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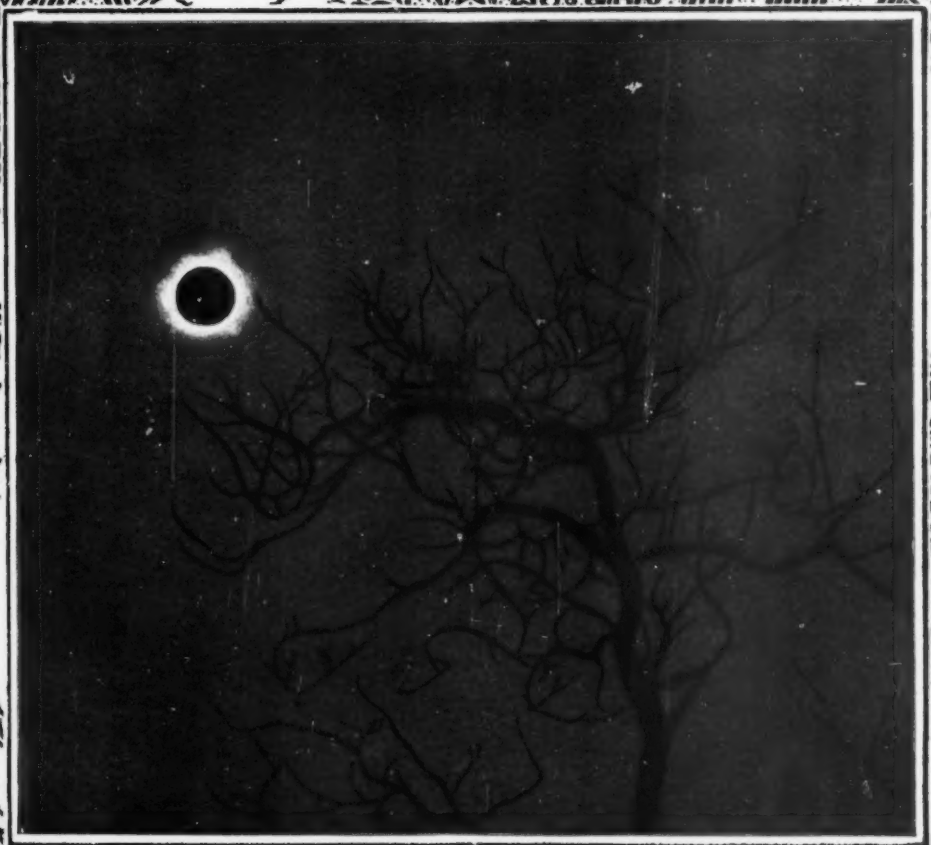
ASTRONOMY NUMBER

NATURAL HISTORY



JOURNAL OF THE AMERICAN MUSEUM OF NATURAL HISTORY

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THE AMERICAN MUSEUM OF NATURAL HISTORY

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NATURAL HISTORY

THE JOURNAL OF THE AMERICAN MUSEUM

DEVOTED TO NATURAL HISTORY, EXPLORATION, AND THE DEVELOPMENT OF PUBLIC EDUCATION THROUGH THE MUSEUM

ASTRONOMY NUMBER

CLYDE FISHER, EDITOR

JULY—AUGUST, 1926

[Published August, 1926]

VOLUME XXVI, NUMBER 4

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NATURAL HISTORY

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From a copyrighted photograph by Dr. Clyde Fisher

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Chaucer's

Troilus and Cressida.

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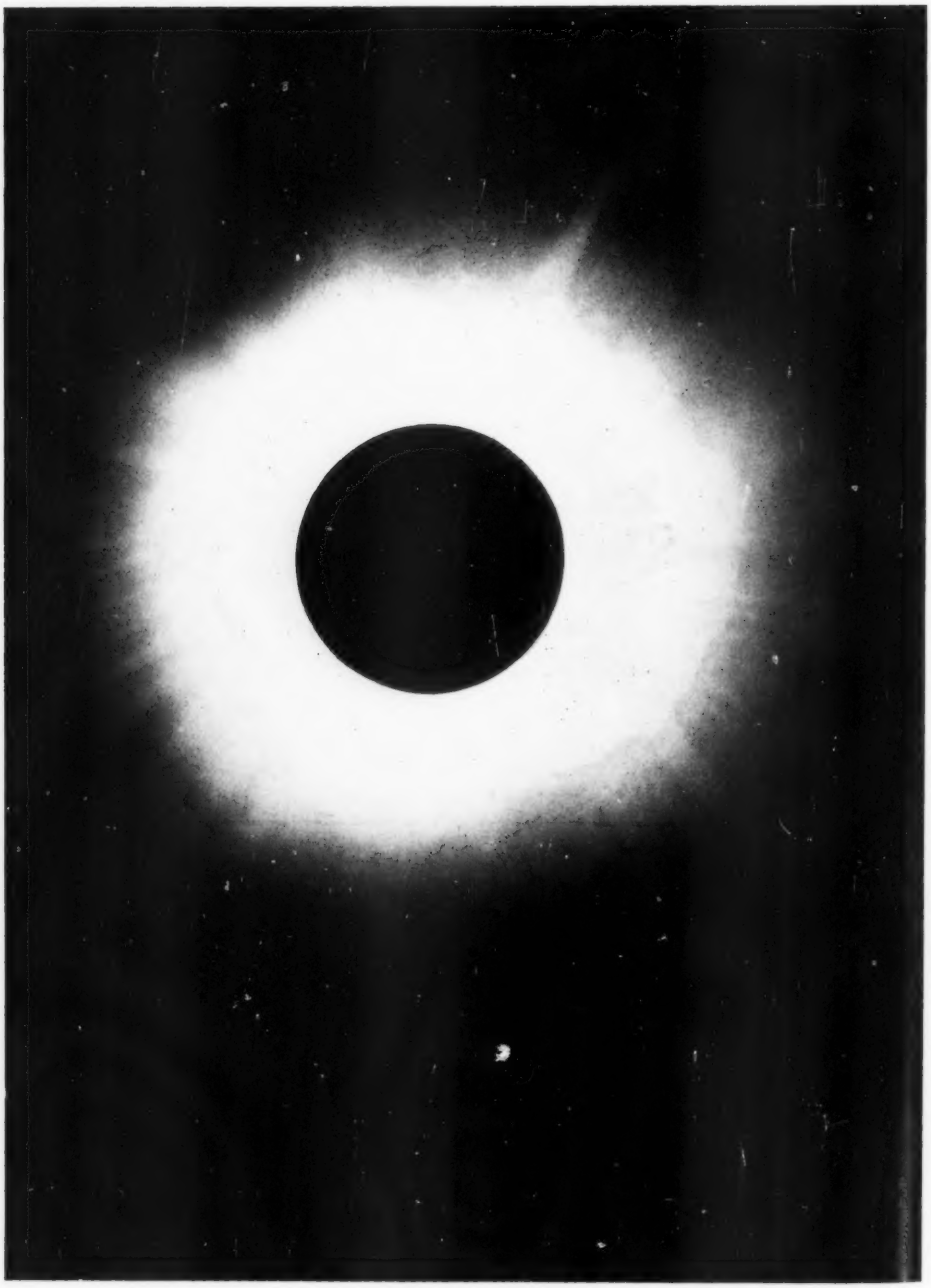
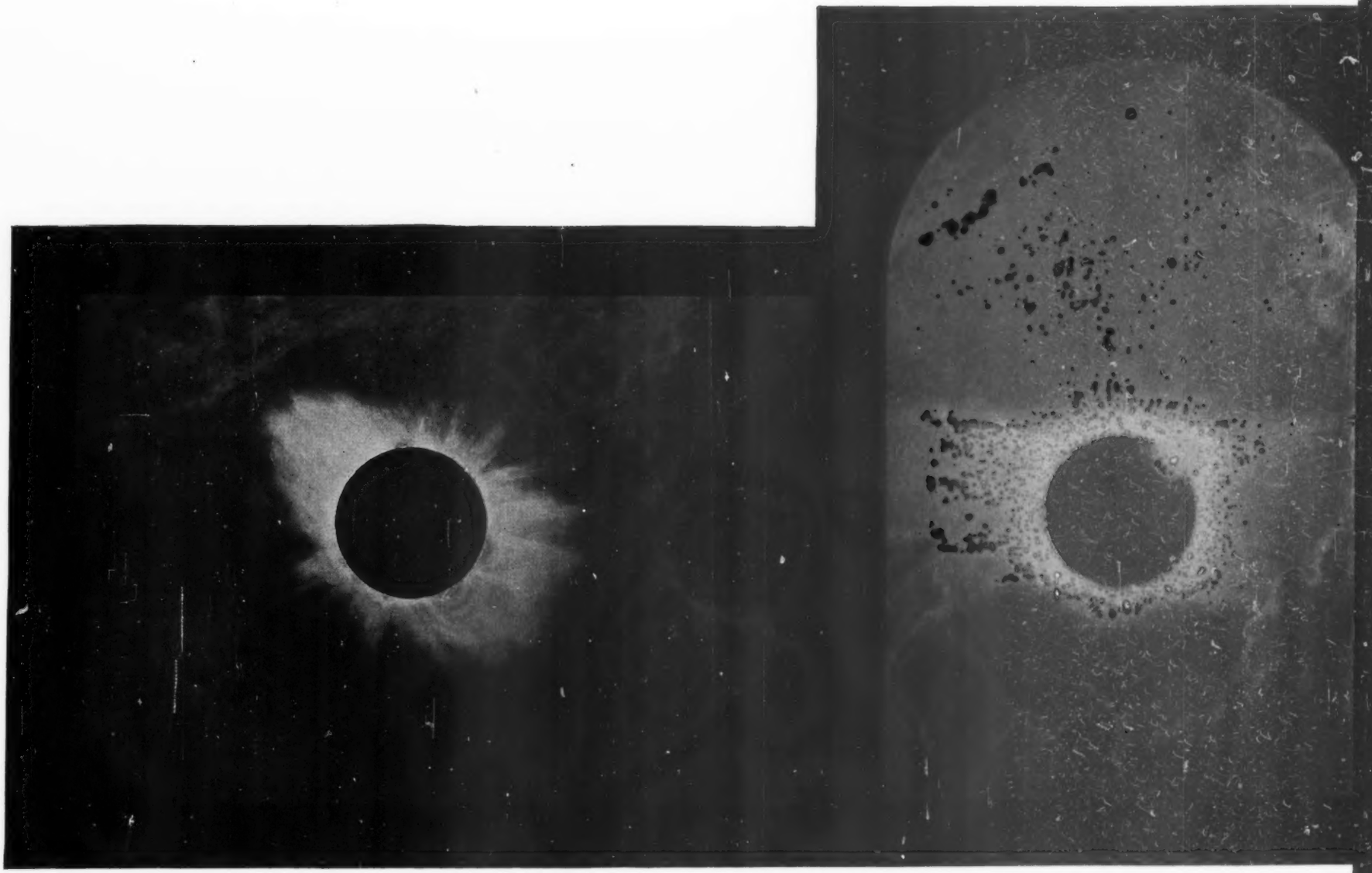
"And there he saw, with full advisëment,
Th' erratic sterrës heark'ning harmony,
With soundës full of heavenly melody
And down from thennës fast he gan advise
This little spot of earth ....."



Photograph by John A. Miller

THE LATEST PHOTOGRAPH OF THE SOLAR CORONA

Taken by the Swarthmore College Expedition in Sumatra on January 14, 1926, with a camera of 15-feet focus. The shape of the corona is nearly circular, exhibiting the type associated with a maximum of sun-spots



THE THREE SOLAR ECLIPSES SEEN IN THE UNITED STATES

FROM THE PAINTINGS BY HOWARD RUSSELL BUTLER

This series of eclipse paintings had its inception in the engagement of Mr. Butler by Mr. Edward Dean Adams to paint the eclipse of 1918, and Mr. Adams' subsequ
Proposed Hall of Astronomy, plans of which are now exhibited for the first time, and represents the first example of Amer

THE OREGON ECLIPSE, 1918

Totality Lasting 112 Seconds

As seen by Mr. Howard Russell Butler at Baker, Oregon on June 8, 1918. The eclipse reached totality at 4:03 P.M. at an altitude of about 45°, and since it was in the afternoon the long axis of the corona was inclined to the right. The time was near the period of maximum sun-spots, and as was to be expected, there was a diminished corona, but with more polar streamers than were expected. The prominences, reached exceptionally large proportions, the "Heliosaurus" measuring 47,000 miles in height.

Gift of Mr. Edward Dean Adams to the American Museum of Natural History

THE CALIFORNIA ECLIPSE, 1923

Totality Lasting 140 Seconds

As seen near Lompoc, California, on September 10, 1923. This eclipse reached totality at it was almost a noon-day eclipse, the long axis of the corona was practically horizontal. The period of minimum sun-spots, and as was to be expected, the corona was more extended.

Mr. Butler's painting shows the first Baily's bead of the third contact, that is, the first a of the photosphere, evidently between two volcanic peaks on the rough surface of the moon.

Gift of the Morris K. Jesup Fund to the American Museu

E SOLAR ECLIPSES SEEN IN THE UNITED STATES IN 1918, 1923,

From the paintings by Howard Russell Butler

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ns of which are now exhibited for the first time, and represents the first example of American Museum methods of e

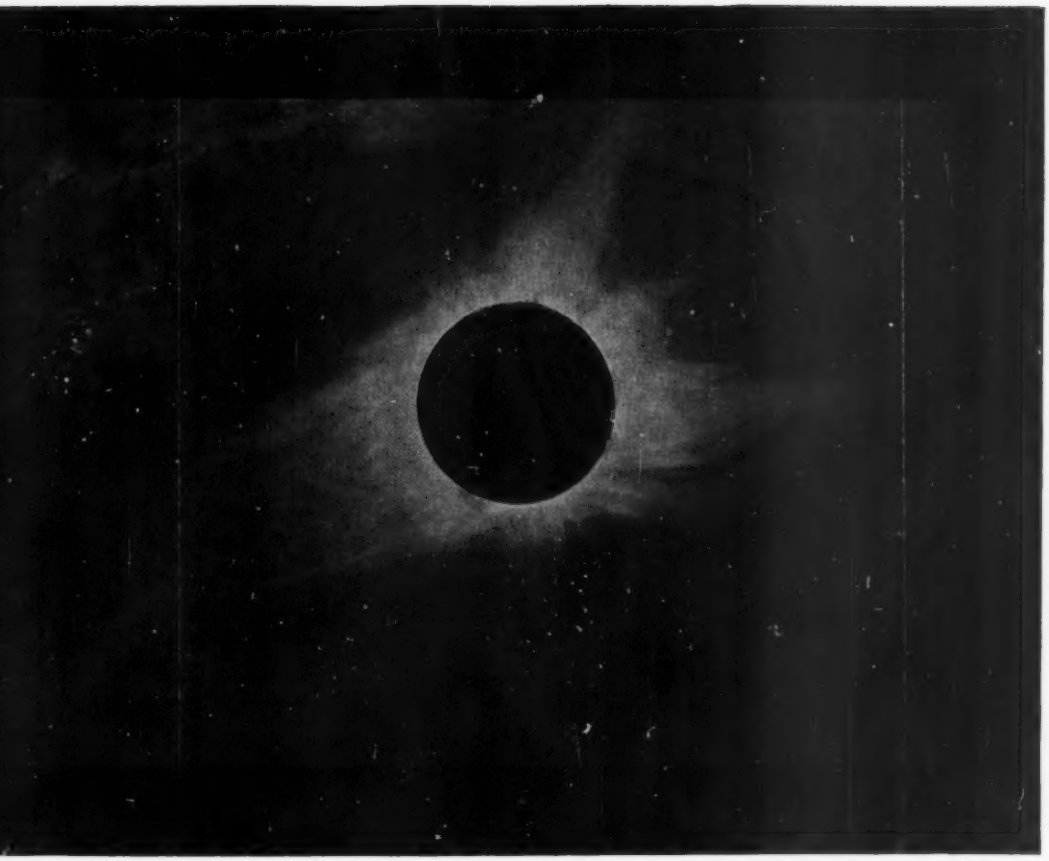
THE CALIFORNIA ECLIPSE, 1923

Totality Lasting 140 Seconds

As seen near Lompoc, California, on September 10, 1923. This eclipse reached totality at 12:59 P.M., and since it was almost a noon-day eclipse, the long axis of the corona was practically horizontal. The time was nearer the period of minimum sun-spots, and as was to be expected, the corona was more extended.

Mr. Butler's painting shows the first Baily's bead of the third contact, that is, the first appearance of a speck of the photosphere, evidently between two volcanic peaks on the rough surface of the moon.

Gift of the Morris K. Jesup Fund to the American Museum of Natural History



, 1923, AND 1925

ainting to the Museum. The present Triptych has been designed by Mr. Butler for the
nethods of education applied to Astronomy.

THE CONNECTICUT-NEW YORK ECLIPSE, 1925

Totality Lasting 110 Seconds

As seen at Middletown, Connecticut on January 24, 1925. This eclipse reached totality at 9:12 A.M., and consequently the long axis of the corona was inclined to the left. The time was near the peroid of maximum sun-spots and not only was the outline of the corona surprising to astronomers, but some of the streamers were much longer than was expected. The prominences, while many (19 were recorded by camera), were so small that they could not be seen by the naked eye.

Gift of the Morris K. Jesup Fund to the American Museum of Natural History

UNIV. OF MICH.

NATURAL HISTORY
VOLUME XXVI JULY–AUGUST, 1926 NUMBER 4

Personal Experiences at Eclipse Expeditions

BY S. A. MITCHELL
Director of the Leander McCormick Observatory, University of Virginia

WITH A SUPPLEMENT IN COLOR OF THE THREE SOLAR ECLIPSES SEEN IN THE UNITED STATES IN 1918, 1923, AND 1925[1]

THE observation of a total eclipse of the sun is one of great excitement and nerve-racking tension. The life of an eclipse astronomer may be likened to that of a hunter after big game. Many months and even years are spent in quietly investigating the problems, a costly equipment is accumulated and each piece of delicate apparatus is carefully tested at home to see that it will properly perform its designated functions at the critical moment. After some weeks spent in the field erecting the instruments and most carefully adjusting the cameras and spectroscopes, the eventful day approaches. Each and every one of the observing party becomes more and more intense and keyed up for the great event. A successful attack lies only in taking care that every one of the possible chances of failure is obviated. When the "zero-hour" arrives, bringing with it the total eclipse, will the attack be successful or will some little blunder spoil everything or will cloudy skies render of no avail all the long months of preparation and show only the eclipse entirely eclipsed by clouds?

Today, as never before, our daily life follows its course surrounded by the wonders of science. But amongst all the wonders of all the wonderful sciences there is no science which deals with such a gorgeous spectacle as is exhibited by the queen of the sciences, Astronomy, at the moment when the earth is gradually shrouded in darkness and when around the smiling orb of day there appears the matchless crown of glory, the beautiful corona. Nor can any science duplicate the wonderful precision shown by the work of the astronomer in his capacity to predict hundreds of years in advance the exact hour and minute at which an eclipse will take place and the locality on the earth's surface where such an eclipse will be visible.

These predictions are not the product of clairvoyance or necromancy, but come only as the result of long continued series of observations carefully carried out by astronomers of all ages and of all climes, and hence are the direct consequence of the faith kept by one generation of astronomers in handing down the torch to the succeeding generation.

If no high degree of accuracy is necessary, the predictions can be carried out with sufficient precision by means of the Saros, an interval of 6585 days, known to the Chaldeans three thousand years ago. An eclipse of the sun can take place only at the time of the new moon, and also when the moon is near the plane of the moon's orbit, called the ecliptic, i. e., when the moon is near her node. Owing to the rotation of the axis of the moon's orbit, the sun passes the moon's node after an interval of 346.620 days which is known as the "eclipse year." Nineteen eclipse years amount to 6585 days and the same number of days are found in 223 ordinary lunar months. After this interval

[1] Extra copies of this Triptych, flat and without lettering, suitable for framing, may be obtained for Fifteen Cents each from the LIBRARIAN, AMERICAN MUSEUM OF NATURAL HISTORY.

the distance from sun to earth and from earth to moon (on which the conditions of the eclipse depend) are repeated very nearly the same as at the preceding Saros with the result that the length of the totality is nearly the same as it was at the eclipse 6585 days earlier. This interval amounts to 18 years, 11 days, if four leap years intervene, or 18 years and 10 days if the 29th of February has come five times.

By means of the Saros it is possible to trace the conditions which cause an eclipse. A partial eclipse of the sun is followed after eighteen years by a partial eclipse, a total eclipse by a total eclipse with a duration nearly the same as that of the eclipse preceding it in the Saros. In such an eclipse series there are anywhere from 68 to 75 solar eclipses depending on conditions, extending over some 1200 years. Of these 25 are partial eclipses, while 45 are central eclipses, of which only 18 are total and 27 annular.

The first eclipse in the cycle which includes that of January 24, 1925, appears to have been a partial eclipse visible on May 27, 933, only in far southern latitudes on the earth, while the last eclipse of the cycle will be on June 25, 2177 in high northern latitudes. The first total eclipse of the cycle was on June 8, 1564.

After the occurrence of three total eclipses of the sun in the United States in the short space of seven years, it is very surprising to find that in the remaining years of the twentieth century total eclipses visible under good conditions appear to shun both the United States and Canada. The next total eclipse in this part of the world will be on August 31, 1932, but totality will be witnessed only along a short track in the United States in the state of Maine.

THE ECLIPSE OF JUNE, 1918

In NATURAL HISTORY, VOL. XIX, 244–263, an account is given of the first of the three American eclipses, that of June, 1918, and only brief reference need be made here to the scientific results sadly hampered by thin clouds that almost everywhere greeted the observing parties. The novel feature at this eclipse owes its inception to Edward Dean Adams of New York, a patron of science and art, who became a member of the eclipse expedition on the condition that he be "given a job." Mr. Adams took upon himself the responsibility of trying, by some method, by photography, by a drawing, or by a painting, to procure a reproduction which would show the gorgeous beauty of the corona, and which should be true not only as to form but more especially as to color. Mr. Adams was very fortunate in finding Howard Russell Butler, a portrait painter of note who was well equipped for the task by having developed a shorthand method of noting both form and color. Unfortunately, the artist had never seen a total eclipse. When he arrived in Oregon ten days before the eclipse he had rather lurid ideas, obtained from reading astronomical books, of the appearance of the corona. It was necessary to take him in hand, tone down somewhat his vivid impressions, and show him the colors of the red and blue hydrogen lines in a powerful spectrograph and then criticize the trial paintings of a typical eclipse that he made in the days before the eclipse. He was an apt pupil and had his plans so well laid that he took full advantage of the 112 seconds of totality furnished him. His painting which Mr. Adams has presented to the American Museum of Natural History is exquisitely beautiful, a work of fine art in which

the painter has not forgotten that scientific accuracy is the first desideratum when recording an astronomical event. Accordingly, the scientific world owes a great debt of gratitude to Mr. Butler for his painting, but even a still greater debt to Edward Dean Adams, through whose conception, generosity, and enthusiasm the painting of the corona became possible.

THE ECLIPSE OF SEPTEMBER, 1923

On September 10, 1923, the moon's shadow touched the earth's surface at sunrise in the Pacific off the coast of Japan. The shadow traversed the ocean at a speed well over a thousand miles per hour and appeared off the coast of southern California somewhat after noon. After crossing lower California, Mexico, and Yucatan, the eclipse ended at sunset in the Caribbean Sea somewhat north of British Guiana.

Fortunately the total eclipse track in 1923 passed over a portion of southern California where one naturally expects superb conditions of weather. According to a well-known American humorist, "When the scientists said that Los Angeles was only to get a 99 per cent eclipse (that is about the only thing I ever knew Los Angeles to fall down on, they are usually 100 per cent) it rather hurt their pride. It was the first time that Nature had ever handed them a mere 99. I don't really think they would have gotten over it but San Francisco only received some 85 or 90 per cent, so that somewhat salved things over. But the Chamber of Commerce has held a meeting and voted resolutions to apply for the next eclipse in its entirety. They claim that it was due to the Club's not giving the matter more thought that they lost the 1 per cent on this one." Everyone, indeed, has heard of the boasted climate of southern California, the "land of sunshine and flowers."

As the result of all the information available about the weather, the best spot for the University of Virginia eclipse expedition seemed to be San Diego, the only large city in the United States inside the path of totality. Within the memory of the oldest inhabitant there had not been a single cloudy day on the tenth of September. To make matters almost ideal, the total eclipse came at one o'clock when the danger from sea-fog was reduced to a minimum. A conservative estimate placed the chances of perfect conditions at about 90 per cent. In fact, the chances appeared so high that it seemed poor business to insure against clouds (which one of the insurance companies was willing to write).

On arrival at San Diego we found that arrangements had been made for the McCormick Observatory party to locate within the military reservation at Fort Rosecrans. Six weeks before the eclipse we found ourselves in a furnished house of ten rooms and two baths, the former home of a major. Meals were sent in from the company kitchen,—and Rosecrans boasted of the "best cook in the Army!"

San Diego has every reason to be proud of her city, located as it is in one of the finest spots of the globe and blessed with an agreeable climate that might well be the envy of any city in the world. We from Virginia, a state which has never been backward in painting a halo around everything connected with the Commonwealth, were much interested in the spirit of civic pride and aggressiveness, which at times may have bordered upon boastfulness. Our six weeks' stay was filled

with pleasant memories and we only wish that each and every total eclipse might be observed under the congenial surroundings of Fort Rosecrans.

Many are the problems that may be attacked at the time of a total eclipse. One of the most important is the confirmation of the bending of the rays of light from a star as these rays pass close to the edge of the sun, as predicted by Einstein. We had no equipment for this research and we preferred to let others tackle this problem while we devoted ourselves to following up the line of attack carried out at four previous eclipses. It was therefore decided to have two stations for observing the eclipse, each equipped with a powerful spectrograph for ascertaining the constitution of the gases forming the sun's atmosphere and also the heights in miles that each of the vapors extend above the surface of the sun. One of these was located on Point Loma, near our temporary home, the other at Lakeside, twenty-five miles inland, and near the edge of the shadow cast by the moon. The essential part of the spectrograph was a concave grating ruled by Rowland of Johns Hopkins. Each of the gratings used was made by ruling on a spherical concave mirror of speculum metal 15,000 lines to each inch. The Point Loma grating was four inches in aperture and thus had 60,000 ruled lines. This grating was used by the writer at the eclipse of 1905 in Spain. The Lakeside grating of 90,000 lines was used at the 1918 eclipse.

The sun is the nearest of the fixed stars, and it is the only star which permits us to examine its atmosphere in detail at the time of a total eclipse. A knowledge of the heights attained by the solar vapors gives information regarding the pressures under which the spectroscopic lines take their origin. At very reduced pressures in the sun's chromosphere and at the high temperature found there it is readily possible for an atom to lose an external electron and become ionized. The spectrum of the ionized atom differs very much from that of the neutral atom which has not lost an electron. In the ionized spectrum certain lines are enhanced in intensity and these are the lines which are stronger in the spectrum of the electric spark than in the electric arc. Knowledge of these things are of the very greatest importance in furthering our knowledge of the chemical atom, a quest in which astronomy, physics, and chemistry are vitally interested.

Other problems of the eclipse are connected with the investigation of the corona. What is it? and whence comes its light? Its feeble light has been traced to the enormous distance of ten millions of miles from the sun's surface. It cannot be a true atmosphere consisting of gaseous particles for, if it were, the pressure at the sun's surface would be colossal, and we know for certain that such pressures do not exist. As a further proof we know that occasionally comets come close to the sun's surface, dashing by the sun at the rate of a hundred miles per second,—and yet the comet goes through the corona without any friction and without any perceptible impeding of its velocity, which would be impossible if the corona contained much matter. The only true atmosphere possessed by the sun is the chromosphere which stretches up to a maximum height of 10,000 miles.

We must rely mainly on the spectroscope to give information on the constitution of the corona. On account of the feebleness of its light it is almost impossible to use a dispersion exceeding that of a single prism. None of the lines in the spectrum of the corona

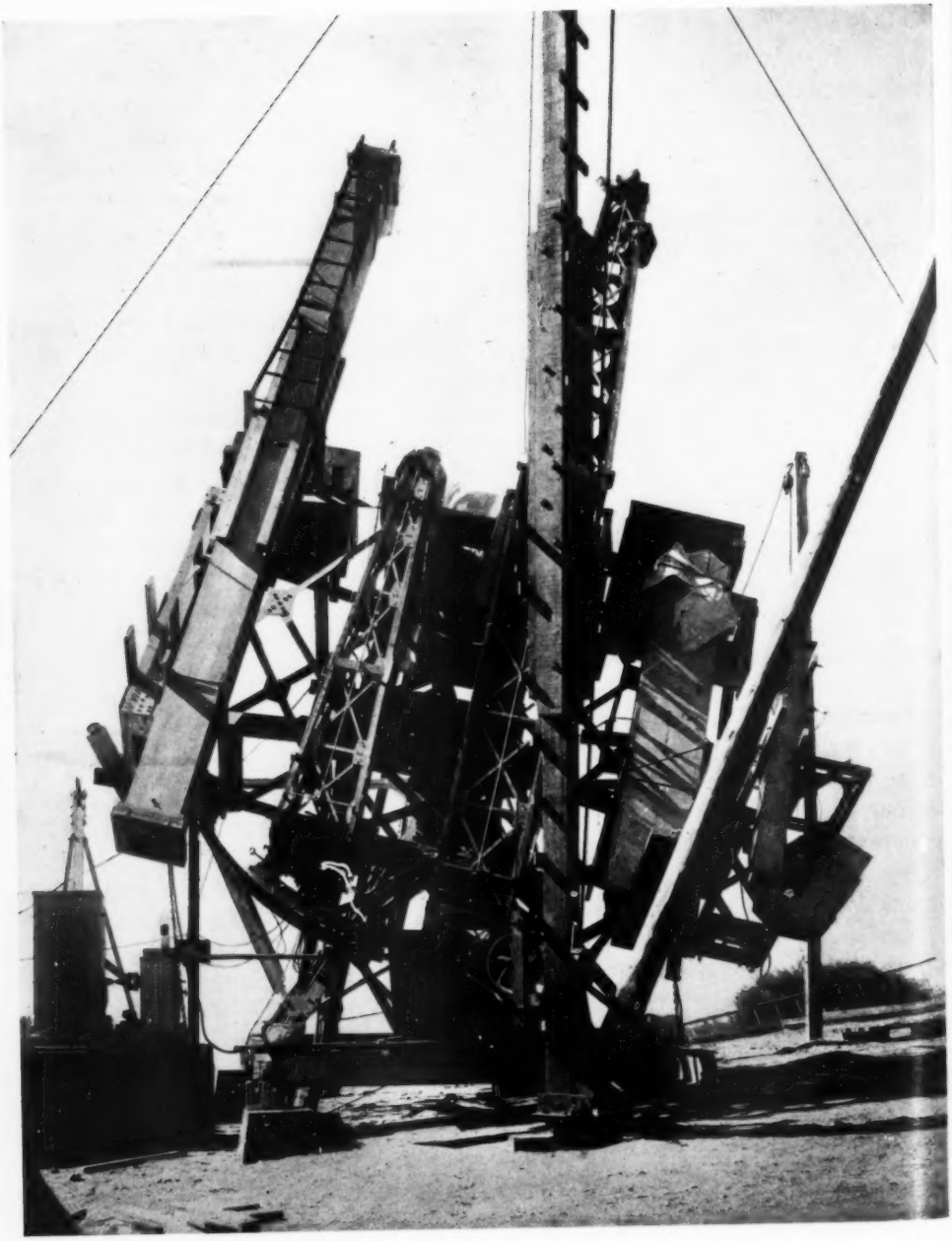
amounting to about forty, has been identified with terrestrial sources. The strongest line in the whole spectrum is in the green, at wave length 5303. This belongs to the mysterious and unknown element "coronium." Part of the coronal light takes its origin from the gaseous coronium which gives a spectrum of bright lines, and part by sunlight reflected from the molecules of the corona, since a dark Fraunhofer spectrum is observed. It has always been difficult to decide whether the reflection and scattering of the ordinary sunlight is in the corona itself or whether it takes place in our terrestrial atmosphere.

Soon after our arrival, the San Diegans discovered us, and before long, invitations began to roll in upon us to address the University Club, Rotary and Kiwanis, the Lions' Club, etc., at their weekly luncheons, and to give public lectures at night illustrated by lantern slides. At the first of the public lectures, given in one of the city schools, more than fifteen hundred people were turned away for lack of room. The following week a lecture was given in the Civic Auditorium in Balboa Park to an audience of five thousand.

As the day of the eclipse approached the interest aroused in the gorgeous spectacle was very great. If we had been so inclined, we might have spoken morning, noon, and night. But there was work that must be done, work that could not wait,—and much as we like to speak in public, we had to try and transfer to some other visiting astronomer the doubtful honor.

An unusual opportunity awaited science at this eclipse. At North Island was the powerful battle squadron of the Naval Aircraft forces. Here was a chance to employ photography from the air on any of the problems that could be solved by this method. It is manifestly impossible to use any but comparatively small cameras from an airplane and to give any but very brief exposures. On account of the short exposures permitted, no spectroscopic work could be attempted from the air, no investigation of the Einstein effect and no photography of the corona that demanded large focal scale. Airplane photographs could not compete with those taken from a fixed installation on terra firma. In the event of clouds and the possibility of soaring above them in a machine, airplane photographs might be taken, but there would be little of scientific value in photographing the corona on such a small scale. There seemed only one direction in which airplane photography could assist the astronomer, and that was in the attempt to find the position of the moon in the sky with greater accuracy, for in spite of the many refined researches of the mathematical astronomer, the motion of the moon is far from being known with the precision desired. The moon is erratic in her motions and quite in keeping with her feminine gender. The position of the moon affects the time of the prediction of the eclipse and the projection of the moon's shadow on the earth's surface.

The program finally adopted consisted in the attempt to photograph from five separate stations along the northern edge and one at the southern edge on the shore of Mexico, the edge of the shadow of the moon. For this purpose it was necessary to use the best of mapping cameras known to the photographers and to choose special sites to photograph where the terrain would offer as great contrast as possible between a point just inside and one just outside the moon's shadow. Incident-



MT. WILSON INSTRUMENTS BEING ASSEMBLED FOR THE ECLIPSE OF 1923

ally it must be admitted that so little was known of the amount of light to be expected a few feet outside of the moon's shadow that there was some doubt as to the final success of the investigation. But there was nothing to do but to "try and see what happened."

During the erection of our apparatus it was interesting to watch the gradual installation of the gigantic equipment to be used on eclipse day by the astronomers from the Mt. Wilson Observatory. This great observatory, the best equipped and most famous in the whole world, is located on Mt. Wilson near Pasadena. Being therefore only about 140 miles from the eclipse site, it was possible to transport all of their instruments by motor truck from observatory to eclipse camp.

In planning the work for the eclipse, Director Walter S. Adams utilized the interferometer mounting on which to place the cameras, spectroscopes, photometers, etc., of the eclipse program. The longest camera was thirty feet in focal length, used to photograph the Einstein effect. Another camera half this length was for the same purpose. There were cameras to portray the beauties of the corona in various scales and in different colors of light, spectroscopes to ascertain the constitution of the corona, instruments to photograph and to measure visually the intensity of the light of the corona at various angles from the edge of the sun. The instruments numbering fifteen made the most complete equipment that had probably ever been assembled in one place for photographing a solar eclipse. The personnel included about thirty members of the Mt. Wilson staff, while an auxiliary party of twenty computers and friends of the staff were prepared to watch and measure shadow bands, etc.

Between this site and the Spanish lighthouse was the installation of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Captain Ault, Mr. Johnson, and many assistants were prepared to measure the magnetic and electric elements connected with the coming of the eclipse. Fortunately for them they could look on the weather with unconcern for it made little difference to their measures whether the weather was clear or cloudy on eclipse day.

The most of us could have no such smug satisfaction as the day of the eclipse approached. The weather indeed seemed "unusual" (we understood this is the first word that a California baby learns at its mother's knee). At any rate the cloudless skies that we had been led to expect at 1:00 P.M. were not always forthcoming. During the first two weeks of our stay at Point Loma high fog at noon was the rule rather than the exception. Still it was a long time to the eclipse, and conditions would undoubtedly improve,—and they did. The next two weeks gave perfect skies, an absence of wind and altogether ideal conditions. Would this last, or would another cloudy spell come? We were optimists and believed implicitly what our friends the Californians told us.

Saturday, September 8, was a gloomy day and the eclipse would have been under poor conditions. Sunday was even worse. What would Monday bring? At eight-thirty Monday morning we were off on our trip to Lakeside. As we got inland from the Pacific, out of reach of the high fog, and where ordinarily we got out of clouds, the conditions improved but little. At ten o'clock at Lakeside we found high cirrus and the conditions looked hopeless. But there were three good hours

until the time of totality and much to be done in the final preparations! By twelve o'clock we heard the airplane aloft which was to observe over Lakeside and the pilot waved to us in friendly greeting. The clouds were not very heavy but there were no clear patches anywhere. We kept a stiff upper lip and refused to believe that after so much bragging California was going to get a black eye.

Still the clouds were not too thick to prevent us watching the diminishing crescent of the sun as totality approached. Nature was hushed but the cocks were crowing lustily as if night were falling. At the very second when expected, the sun was blotted out and a faint trace of corona appeared. But what a bitter disappointment! We carried through our program, exposing eight plates in the seventy seconds of totality, knowing full well that the developed plates would show not the slightest trace of light.

Well, there was no use crying over it (although one was tempted to). We had done our best and the fault was not ours. If misery likes company, it was evident that the clouds were general and not local. As quickly as a high-powered car could take us to San Diego we telephoned to Point Loma only to find as we expected, that conditions there were even worse and practically not a trace had been seen of the corona. Radio told us that the Yerkes party on Catalina Island had suffered a like fate and that the usual luck of the Lick party had deserted them, for conditions where Doctor Campbell and the Lick expedition were located at Ensenada were as bad as could be.

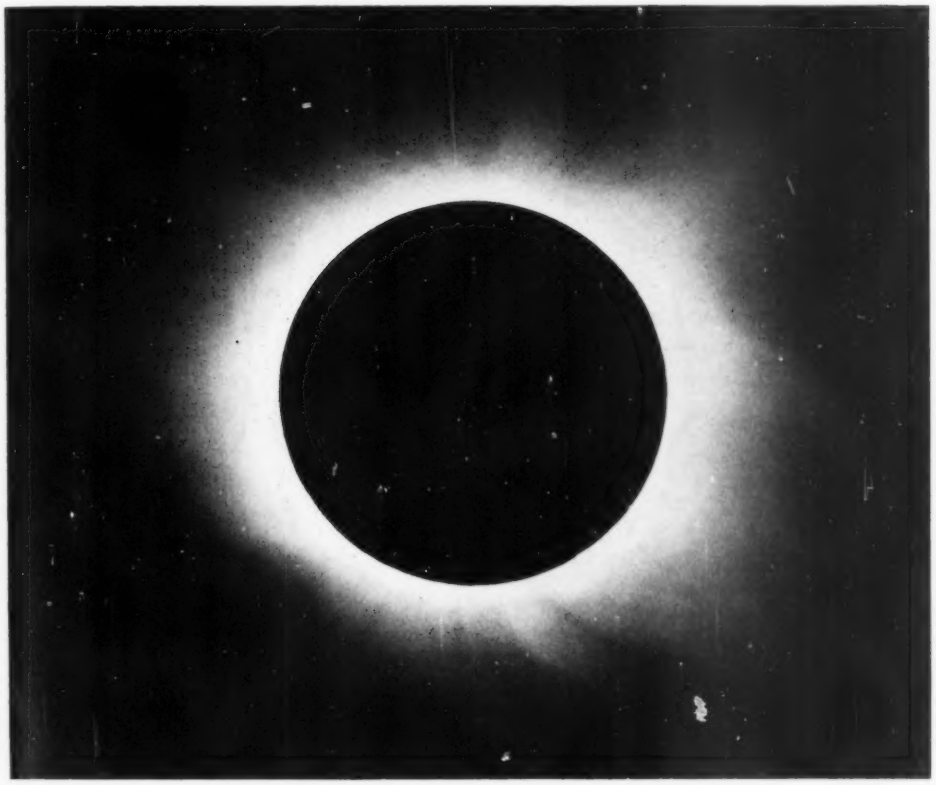
And this was the record for "sunny California"! Not a single expedition greeted with good conditions, and the whole scientific work a dismal failure! There was nothing left to do but pack up and go home,—and then begin to get ready for the next eclipse, that of January 24, 1925. It seemed foolish to expect good weather conditions at nine o'clock of a winter's morning in New York and New England and with the sun low down toward the horizon. But nothing venture, nothing win!

THE ECLIPSE OF JANUARY, 1925

The day before the eclipse of January 24 was one of gorgeously perfect blue skies. Would the morrow provide as good skies? After all the long weeks of preparation and of hard work in installing the instruments, would the work be all of no avail by clouds blotting out the eclipse? As always we were optimists. We astronomers located at Middletown, Connecticut, at Wesleyan University, were all so keenly interested in what we were planning to accomplish that each of us slept the night before the eclipse with one eye open. At six o'clock on eclipse morning my friend Professor Slocum, the director of the Van Vleck Observatory, in whose home Mrs. Mitchell and I were staying, looked out and saw the stars on a brilliant clear sky. He gave voice to his elation by saying "We greet you, sunny California." But this boasting was almost our undoing, for inside of quarter of an hour the sky was thickly overcast with very dense clouds.

What a dejected crowd of astronomers we were at eight o'clock when we had gathered at the Van Vleck Observatory to observe "first contact," the beginning of the eclipse. There was nothing but clouds everywhere!

A quarter of an hour later a ray of hope appeared, there was a blue streak of sky low down in the northwest,—and the clouds were coming



Solar eclipse of January 24, 1925, photographed by Frederick Slocum, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut.

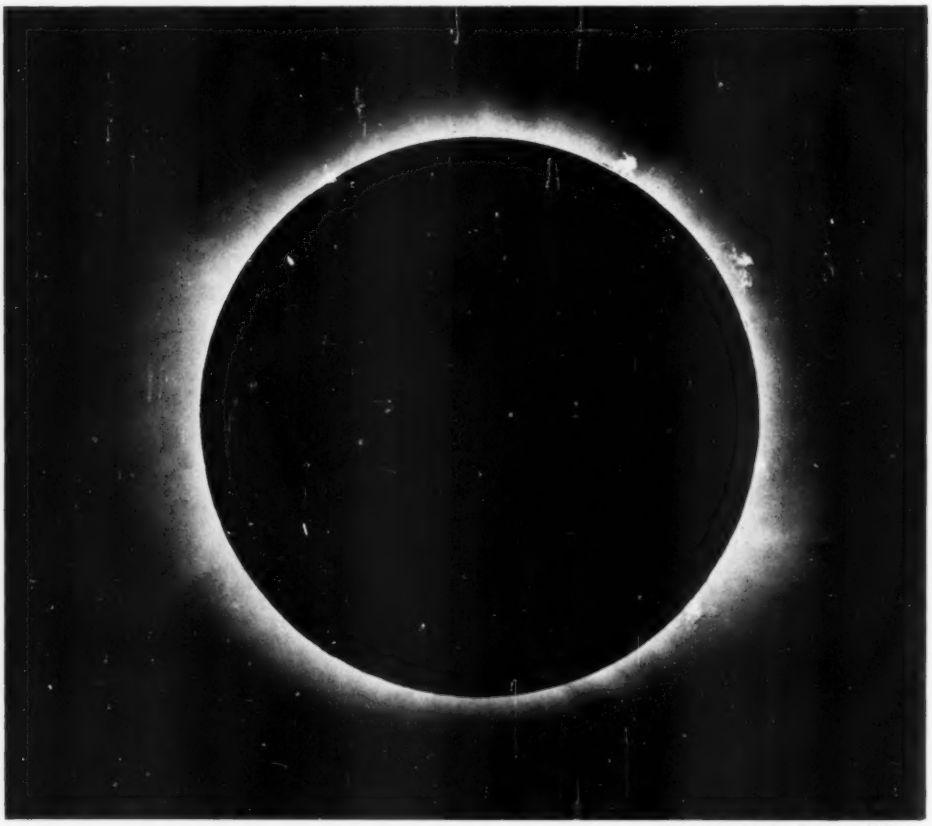
from that quarter. Would it clear off in time! Luck was with us. Fifteen minutes before totality the sun broke through the clouds. Five minutes before totality each observer was at his station and we waited in great expectation. A cloud, very thin and very fleecy, now hung over the sun. It was not thick enough to do much damage and it was moving slowly. We hoped it, too, would go. When the timers called out "Two minutes," the cloud was almost gone. By now it was beginning to get quite dark, a weird and unnatural pall coming over the landscape. The observers outside noted shadow bands flickering over the snow. At one minute before totality, with the thin crescent of the sun growing very small, the atmospheric conditions seemed perfect, the thin cloud had gone.

The signal "Thirty seconds" rang out. Everything was hushed while we waited for the zero hour, the beginning of totality. In my right hand I had a pair of binoculars over the right glass of which was a grating for observing the flash spectrum visually. When I saw it flash out, I gave the signal, "Go"; totality had begun; and with my left hand I opened the shutter to begin the first exposure.

As a spectacle, the 1925 eclipse suffered from its taking place so early in the morning. If the darkening had come on during the middle of the day with the sun high up in the sky the psychological effect would have been

all the greater. Still it was a gorgeous sight!

It will be impossible in this short article to give in detail an account of the scientific discoveries from the 1925 eclipse. Valuable information was gained about the intensity of the corona whose total light is about equal to the light of a standard candle at the distance of a meter. Compared with full-noon sunlight the corona gives one-millionth of the light of the sun and about half that of the full moon at its average distance from the earth. The surface brightness of the corona at the limb of the sun is about 1.4 times that of the full moon, and half the total light of the corona comes from a zone extending only 3′ from the edge of the sun.



Photographed by John A. Miller

Photograph of the inner corona at the 1926 Sumatra eclipse. Taken by the Swarthmore College Expedition with a camera of 63-feet focus pointed directly at the sun. Note the prominences and the curved hoods covering the prominences

So far in the history of astronomy it has been impossible to detect the corona without an eclipse. The difficulty is that the coronal light has superimposed upon it the enormously greater illumination near the sun produced by the scattering of sunlight in our atmosphere and in the telescope. The effect of the illuminated atmosphere is ten thousand times more intense than the corona near the sun's limb, and hence the astronomers hold out

no hope of detecting the corona—at least with present observational means—at any time other than at an eclipse.

With the passage of time additional knowledge of the corona will be accumulated with great slowness due to the paucity of time available for observations. There are a few astronomers in the world who have been on more eclipse expeditions than I have been on, but I do not know of any astronomers who have actually seen the corona more frequently than I have. My first eclipse was that of 1900, and in the quarter of a century that has elapsed I have traveled fifty thousand miles in order to witness six eclipses. The total time afforded for observations during the periods of totality of all of these eclipses has made altogether a paltry fourteen minutes. If in the balance of my active career as a professional astronomer I am permitted to observe each and every total eclipse visible anywhere in the world (a condition of affairs that is not at all likely) I would then be the one astronomer throughout the ages that has had the opportunity of observing total eclipses of the sun for the total length of time of one half an hour.

Astronomy, the grandest and most perfect of the sciences, exerts an appeal to the popular imagination that has no equal in any other science. The reason for the universal interest in astronomy is not because it teaches us that this earth of ours is a tiny and insignificant speck in the cosmos but rather for the opposite reason, that man, though he is so small and infinitesimal in size, is gifted with powers which are almost infinite. From this earth of ours the astronomer's brain intelligence can reach out across millions of miles of space and can ascertain what the sun is made of, what its temperature is, what the conditions are in the solar atmosphere, and acquire this information with so much of certainty that we know more of conditions in the solar atmosphere than we do of the terrestrial. Nor are the investigations of the astronomer confined to ninety millions of miles of space. Light from the sun, traveling at the rate of 186,000 miles per second reaches the earth in 499 seconds, a little over eight minutes. Light from the nearest sun outside of our solar system takes more than four years to reach us. But still the astronomer reaches out farther and even farther and he tells with great positiveness and certainty that the nebula in the constellation of Andromeda is so far away that its light takes one million years to reach the earth!

The earth has existed all of this time and even very much longer, for the most competent authorities are confident that Mother Earth existed substantially in the condition in which she now is for at least one thousand millions of years. Truly it is a great stretch of time, measured by man's standards, when we reach back far enough to be able to say, "In the beginning God created the world."

Painting Eclipses and Lunar Landscapes

By HOWARD RUSSELL BUTLER, N.A.

ECLIPSES

WHEN asked if I would accompany the United States Naval Observatory party to Baker, Oregon, and try my hand at painting the solar eclipse of June 8, 1918, I stated that, as a portrait painter, I generally asked for ten sittings of two hours each. But all the time they would allow me on this occasion was 112⅒ seconds. As it turned out I got a trifle more, for their calculation was short by ⅒ of one second.

Of course no actual painting was possible in time so limited and I therefore employed a method of shorthand sketching (which I had been developing and practicing for about twenty years) for recording sunsets and other transient effects. The method is simple, but *does* require practice. I will describe it:

The artist regards his subject as composed of a limited number of what he calls *masses*, in each of which there is a general uniformity of value, i. e., of the position of the *mass* on the scale of brightness—or the scale from black to white.

The shorthand method consists simply in

First.—Quickly drawing the outline of the masses.

Second.—Writing in, on each mass, the formula of its color.

Third.—Locating accurately the points of highest and lowest value.

Fourth.—If time permits, subdividing the masses.

Applying this to the painting of the eclipse of 1918, I realized that drawing the masses would be easy except for the corona. The moon is round, the shapes of the hydrogen prominences could be obtained from photographs, but the corona would be difficult. No photograph gives its full extent. Plates are not equally sensitive and times of exposure vary in length, hence twenty photographs of the same corona give as many different outlines, though a general agreement exists as to the beginnings of the arms or main projections as well as the variations in value, such as arches, etc. The polar rays are so intricate that detail can only be suggested in the rapid drawing but an analysis of many photographs of them gives much information. The eye sees the entire corona to the outermost limits permitted by the optic rays. A general outline of these limits must therefore be striven for, and afterward details from photographs can be advanced to these limits. In 1918 I failed to complete the entire outline in the 20 seconds allotted and so I gave myself more time in 1925. By using my own outline and many photographs of what may be regarded as contours of luminosity I obtained a composite drawing of the 1918 corona.

Next comes the question of determining the formulas of the colors of the masses. This is somewhat difficult and requires practice. My system is based on the "color spindle," as developed by the modern psychologist. As is generally known every color has three constants or dimensions. We will first consider the constant of brightness, or value as the artist calls it. This is represented in the spindle by a vertical axis, neutral as to hue, running from black at the base to white at the top. From this axis, at varying altitudes,

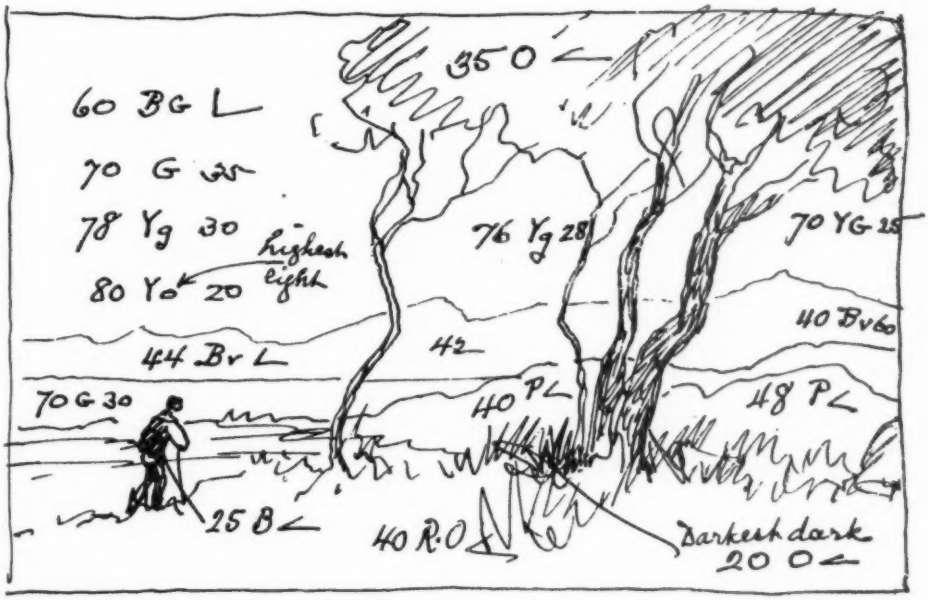


Fig. 1.—Shorthand sketch of sunset, El Capitan Point, near Santa Barbara. Dark blueish-violet mountains seen against a light sky graded from yellow-orange to Robin's-egg blue

radiate spokes representing the second constant or the prismatic hue: red, orange, yellow, green, blue, violet, and purple. The distance out on these spokes gives the third dimension—chroma or saturation. The psychologists tell us there are 30,000 colors which can be differentiated by the average human eye. Each is represented by a point in the spindle and each can be designated by a formula: Thus R.$^{40}/_{60}$ means a red with saturation of 40 per cent and a brightness of 60 per cent. Saturation can be quickly expressed by a sign—a right angle meaning full saturation, an angle of 45 per cent meaning half saturation, acute angles meaning little, down to a straight line meaning none. Where a color becomes neutral, only the brightness or value remains to be recorded. In sketching, it is well to think of the brightness first, then the hue, and lastly the degree of saturation.

Next we consider the lightest and darkest notes in the picture. These may be the masses themselves, as in the case of the eclipse pictures, or they may be accents within the masses.

The key of any picture is determined by the portion of the scale of brightness used. If black is 0 and white 100, a picture low in key might run from 10 to 50; a high-keyed picture, like some of Besnard's frescoes, might run from 70 to 100; a wide key say from 5 to 90.

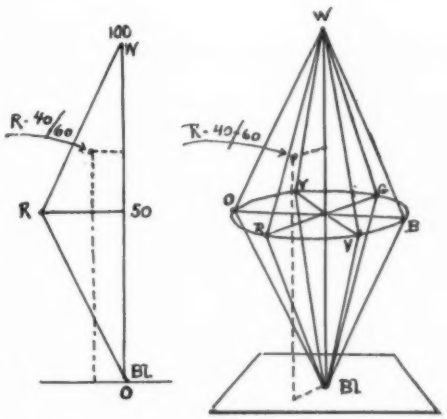


Fig. 2.—Diagram of a "color spindle." The red section is shown separately

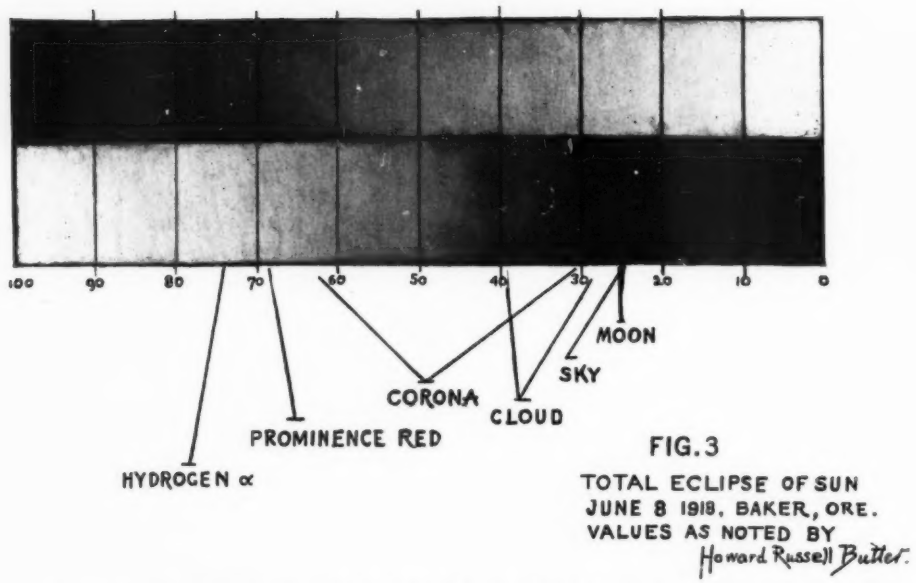


Fig. 3.—A graphic representation of the scale of brightness values of the various colors found in the eclipse phenomena. Varnished ivory black is taken as zero and the best white lead (silver white) as 100 for the points of reference. The most brilliant shades were found in the prominences which consist for the most part of incandescent hydrogen gas with a color approaching that of the red hydrogen line of the spectrum. By careful painting the brightness of the reds used in portraying the prominences was forced up to 67, and a very fiery quality given to them. The brightness of the sky was pitched at 25, as was the moon, while it was estimated that the clouds ranged from 30 to 40, and the corona from about 30 to 60

The addition of any color to white reduces its value, thus, if red be added to white the value descends rapidly.

I realized that in an eclipse picture the key would be very important—a section of the sky with an eclipse going on in it would have a definite key. I wanted to secure the effect of looking through a window at such a section of the sky. So the key would be determined by the extremes of value used. The imaginary window gave an angular dimension to my picture of 2½ degrees, and 20 seconds were to be devoted to looking through Zeiss binoculars giving about that field.

Now the highest light was the mass, very small but very important, of the hydrogen prominences, rich in red almost up to the hydrogen alpha line. To secure this redness I was compelled to reduce the value of my highest note to between 60 and 70. The darkest dark was the blue sky. The moon was about the same. At the time of the eclipse I estimated it at 30. So the range of the values was small and midway in the scale,—a narrow middle key. The formula for the blue sky was 30 B.V.—with a sign meaning strong saturation.

My regular shorthand plan called for more time than was allowed in eclipse painting and so certain modifications were introduced, making the operation a shorthand of a shorthand method.

Thus—realizing that the corona was bound to be brilliant at the edge of the moon and die out into the sky, exhibiting progressive changes in value, I used a rapidly drawn curve between coordinate axes as shown in the illustrations. So much for the values of the corona.

Next for the prismatic hues; expecting that they would be of very low saturation, I painted a sample of pearl-gray on a piece of canvas and tacked it

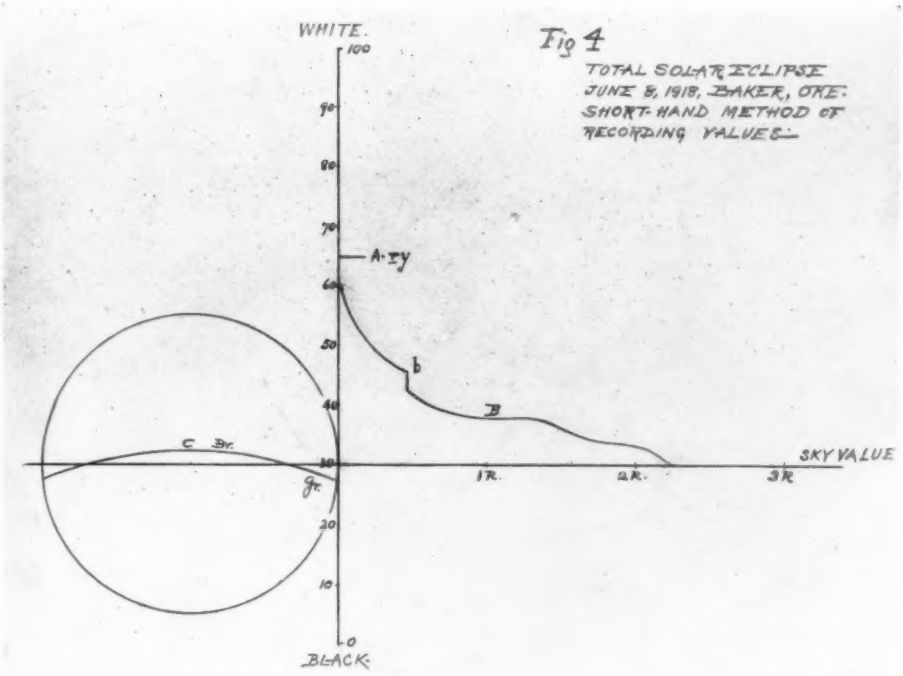


Fig 4

TOTAL SOLAR ECLIPSE JUNE 8, 1918, BAKER, ORE. SHORT-HAND METHOD OF RECORDING VALUES.

Fig. 4.—Two diagrams combined, one illustrating the artist's shorthand method of recording during the few seconds of the eclipse the brightness of the colors in the corona, the other a method of noting the depth of shadow on different areas of the moon's disk. One diagram consists of the two perpendicular lines or axes, and the curve B. The vertical axis represents a scale for measuring the brightness of a color, considering ivory black as zero and silver white as 100. Distance on the horizontal axis measures distance on the sky beyond the moon's edge measured in radii of the moon ("1 R" equals a distance of one radius or half the moon's diameter from the moon's edge). This horizontal axis is drawn through 30 on the brightness scale, that being the estimated brightness value of the sky during the eclipse. A curve drawn between the axis shows the variation in brightness of the corona at any given point, beginning at the inner edge of the corona and passing outward to the dark sky; that is, the color in the inner corona close to the moon is 60 on the scale (or in other words the tone of the inner corona is about three fifths as bright as silver white). From the curve drawn downward from 60 we see that the corona at 1 R (one radius distant from the moon's edge) had fallen to a brightness of about 40, and slightly beyond the length of 2 R it disappears, blending with the sky. The line A is the artist's shorthand to indicate that the prominences had a brightness value of 65 and "ry" is a quick way of recording it if they were "very rosy, tinged with yellow." These two axes were drawn in advance, on the cardboards on which the eclipse was to be drawn, on two sides of the circle of the moon (see Figure 5), being represented as tangents to the moon's circle (see right hand and upper left hand of figure). By means of the curves drawn in on these axes with great speed during the eclipse, we can read off the brightness of the corona's colors at any distance from the moon.

The line C in the other diagram (the moon's disk at the left) is a shorthand way of indicating that the moon was lighter in the center than at the edges and that these edges were darker than the sky. The "Br." and "Gr." indicate a tinge of brown and green respectively

alongside of the white cardboard on which the record was to be drawn. If the gray seemed correct no entry was to be made; parts that seemed yellower were marked with a Y; greener with a Gr. In my haste being unable to see any color in the brightest part of the corona I wrote in the word "whitish."

To aid in the drawing, concentric circles, radii, and tangents were drawn in advance on the cardboard.

A program was tacked to the easel, reading as follows:

	Seconds
Note value and color of sky	10
Draw value line on moon	10
Note colors of moon	10
Draw outline of corona	20
Use Zeiss binoculars	20
Record position of prominences	10
Note color and value of prominences	10
Note color and values of corona	20
	110

In 1918 an officer of the Navy called the seconds. About ten drills were held in advance and at each a finished

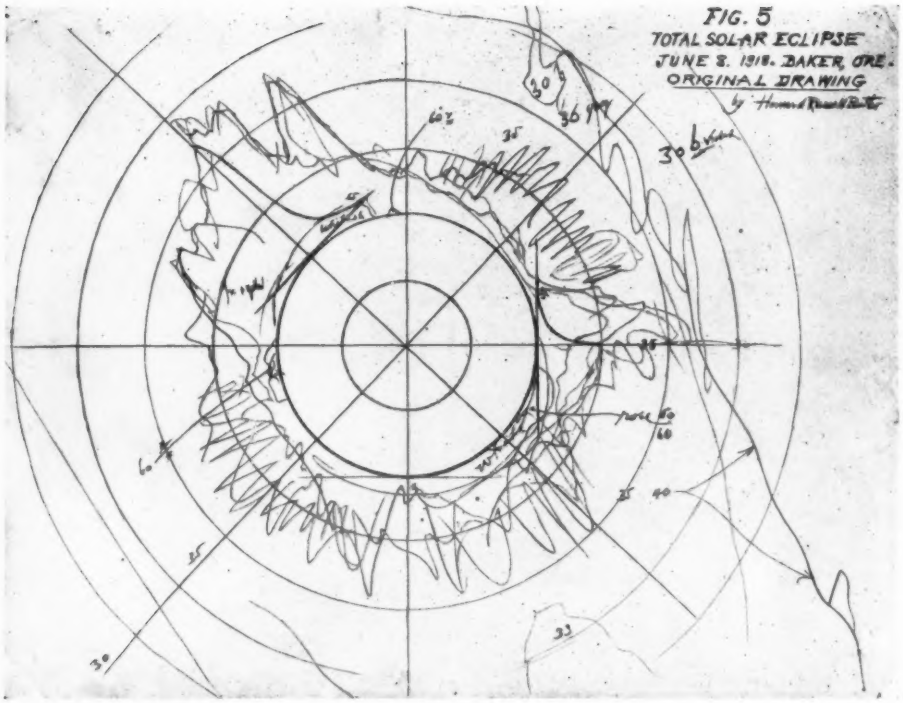


Fig. 5.—This is a reproduction of the actual original sketch, made at the time of the eclipse, on a cardboard on which the radial lines, circles, and tangents had been prepared in advance. This is the artist's record, not only of the general outlines of clouds and corona, but also of the colors which are indicated by initials or words (underscored when the color is intense), and of the brightness of the various parts of the corona, indicated by numbers and by curves such as are explained in the preceding figure. The artist had painted previously a picture of the way in which he "expected" the eclipse to appear and no time was wasted putting in colors or tones which were approximately correct in the prepared sketch

drawing of an imaginary eclipse was made.

When the instant of totality came, the astronomer at the telescope shouted "Go," and I turned (having kept my eyes to the dark northwest to avoid retina-fatigue) and saw the eclipse through a thin film of cloud with blue sky to the right. No time allowance had been made for this cloud and it was necessary to rush matters to gain time for that.

In 1925 at Lompoc, California, I used practically the same method. I could think of no better plan. As the first "Baily's Bead" of the third contact was very beautiful, appearing like an orange ball on the rough edge of the limb of the moon, and as it did not obliterate for several seconds the corona or Venus (slightly over one degree above) I concluded to make that effect the subject of my picture, adding it to the notes previously made.

In 1925 I devoted much time to drawing the corona, realizing at once the similarities of the color to previous eclipses. The sky was very clear and deeply saturated.

LUNAR LANDSCAPES

The Lunar Landscape, from which the colored plate was made, is the joint work of Dr. Henry Norris Russell and myself. It is a view of the earth as seen from the bottom of a lunar crater, the observer standing near a lofty "spine."

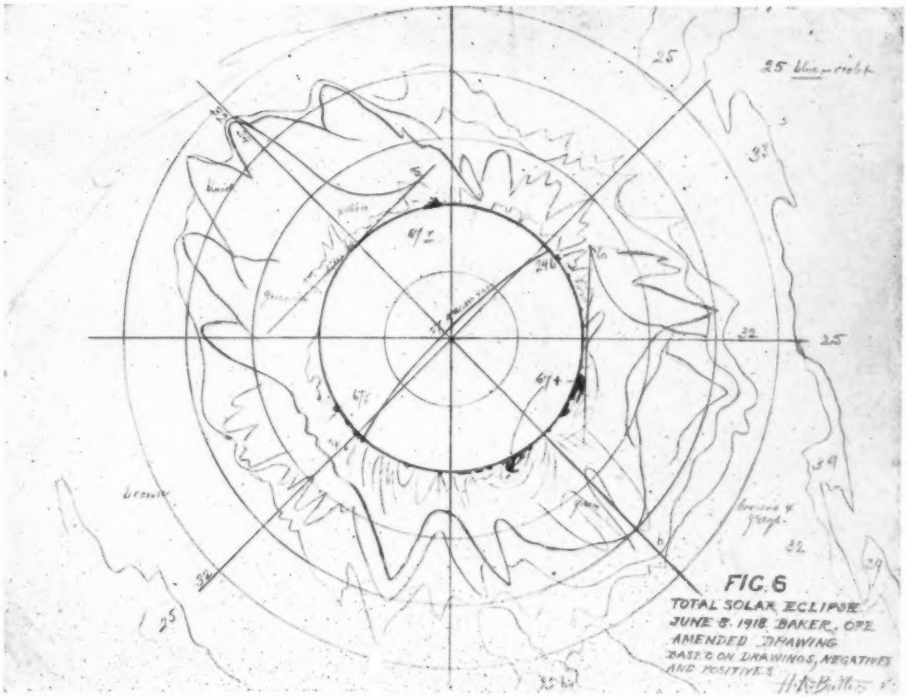


Fig. 6.—The artist's original drawing as amended later by reference to photographs made of the corona. The details of the polar rays and of the prominences had been left for the cameras to record. Careful drawings of these features and of the variations in shading of the corona resulted in this composite picture on which was based the painting of the corona (see color plate of triptych accompanying this issue). The lines outlining the corona in this figure may be regarded as contours of luminosity, showing the range and extent of certain degrees of brilliancy around the disk.

Note: Finding it possible, by process painting, to raise the value of the prominence red, without diminishing its redness, from 60 to 67, the artist adopted the latter figure as his highest light. He also concluded to lower the value of the sky from 30 to 25, thus obtaining a range of 42 points instead of 30, an increase in the ratio of 7 to 5. In this new scale the other values take their proportional places. This is a case of transposition of key. The final painting was made from the transposed key as shown in this figure.

I had long wished to paint a lunar landscape but did not dare to attempt it, realizing my own ignorance. I mentioned this one day to Doctor Russell and he kindly offered me the benefits of his great knowledge. We began by studying the moon's surface through his telescope when it was at the first quarter.

The picture subtends an angle of about 10° laterally and the earth about 2°. The focal distance of the picture is 24 feet—looked at from that point you see the earth only a few degrees above the horizon. It is a daylight picture, the slant of the sun's rays giving a "gibbous" earth and a partial illumination of the mountainous rim of the crater, silhouetted against the black sky. The spine is high enough to catch the sun's rays and has, like many of the lunar cones or spines, an apparent crack or opening at the top. The floor of the crater has been broken into fragments by the upheaval of the spine and these are more or less imbedded in solidified lava flows, with volcanic pits here and there.

The earth is seen with its north pole uppermost and inclined very little from the vertical but showing the north polar ice cap. The Atlantic is toward the observer, presenting a convex mirror in which the sun is reflected near the coast of Morocco. The earth is supposed to be seen in the month of

June. The equatorial cloud belt is shown and a storm is crossing the North Atlantic. Other storms are scattered here and there. Unfortunately these details are not well shown in the color plate, owing to the great reduction.

The earth is seen in the constellation Scorpio and is shown near the serpent's head. Antares is seen to the left of the point of the spine, and Mars, also red, is near the top of the canvas.

In this picture the sky is the darkest mass,—varnished ivory black was used for it. The highest light is the white accent representing the sun's reflection in the Atlantic. The entire range of values—0 to 100—is thus used, depriving the picture of tone and greatly emphasizing contrasts.

We proceeded on the theory that there was no atmosphere on the moon and consequently there would be no diffusion of light. There would, however, be reflected light, especially if surfaces are at all glazed. One-half of the high mountain wall surrounding the observer would be in sunlight and would reflect back into the shadow, giving more or less of sparkle.

Without an atmosphere the values would be unaffected by distance and as the "albedo" of the earth is as a whole far greater than that of the moon, the earth values are made higher than the moon values, so that the earth becomes the most brilliant mass in the picture. All of the earth values however had to be kept below that of the sun's reflection in the convex mirror of the Atlantic.

The apparent surface of the earth as seen from the moon is about fourteen times that of the moon as seen from the earth. The crescent of shadow on the earth would receive so little reflected light from the moon that its value would not differ appreciably from that of the sky.

The colors of the various surfaces on the earth would be seen by light rays penetrating the earth's atmosphere twice (directly and by reflection).

This would probably enhance the blues. Greens would be visible. The outer surfaces of clouds would be as white as the snow caps.

Many times, while making this painting, I longed to be at the spot and see how it really looked. But when Doctor Russell mentioned that the temperature there would be about 70° below zero I was content to abandon that desire. All criticisms will be thankfully received.

THE EARTH AS SEEN FROM THE MOON

Mr. Howard Russell Butler has painted a lunar landscape with the coöperation of Professor Henry Norris Russell, director of the Halsted Observatory at Princeton. It shows the earth in the sky as seen from the moon, the observer being located in one of the rugged lunar craters near a spine thrust up from the crater floor, similar to that which was formed during the great eruption of Mt. Pelée on Martinique in 1902. The earth is represented as in the month of June with the Atlantic toward the observer. It is passing through the constellation Scorpio, Antares appearing near the point of the spine. Mars is seen near the top of the canvas.

Gift of the Morris K. Jesup Fund to the American Museum of Natural History

UNIV OF MICH

Solar Tornadoes

By GEORGE ELLERY HALE
Honorary Director, Mt. Wilson Observatory of the Carnegie Institution of Washington

EVOLUTION may be considered to begin with the formation of the atom, the constitution of the chemical elements, and their union into the various kinds of matter. For the origin of matter we must look to the stars, which recent researches have taught us to recognize as the cosmic crucibles in which the chemical atoms are built up from the elementary electrons and protons. The nearest of the stars—in fact, the only star near enough to the earth to reveal its disk, and thus to permit of study in detail—is the sun, the ancestral body of the solar system. Out of the original substance of the sun, the earth and all the other planets were formed, and they are still dependent upon it for light and heat. Thus from the evolutional standpoint the sun is of double interest to us, both as the nearest celestial laboratory for the production and transformation of matter and as the parent and sustainer of the earth, where after a period of tempestuous youth the seas and land surfaces slowly took form, rose and subsided through the centuries, and became the abode of the many forms of life which finally resulted in the origin and development of man.

The sun is a mass of vapor 865,000 miles in diameter, with an average density about 1.4 times that of water. Toward its center, where the temperature reaches several million degrees Centigrade, its density is far greater than this, but the gases which form its brilliantly white surface (the photosphere) are much less dense than water. Their temperature is between 6000° and 7000° Centigrade. Thus there is a great drop in temperature from the interior of the sun, where most, if not all of the atoms are doubtless split up into electrons and protons, to the surface, where we observe the chemical elements as they appear in the electric furnaces and arcs used in our laboratories. We therefore have every reason to believe that by some process not yet clearly understood the elements are formed from electrons and protons below the photosphere, through which they rise in the gaseous state to constitute the atmosphere of the sun.

The year 1359 was made notable by two outstanding events, which marked the origin of the modern study of organic and inorganic evloution: the publication of the *Origin of Species* by Darwin, and the discovery of the chemical constitution of the sun by Kirchhoff. This first use of the spectroscope for the interpretation of astronomical phenomena showed the existence in the sun of the familiar elements sodium, iron, calcium, magnesium, chromium, nickel, barium, copper, and zinc, identified by the coincidence of the lines in their spectra with the dark lines in the spectrum of the sun. Many other terrestrial elements were recognized later, and it soon appeared that the earth and sun are closely similar in chemical composition.

The vapors thus identified in the sun form the lowest stratum of its atmosphere, a thin sheet closely embracing the photosphere. Above this shallow layer certain gases rise to much greater heights, constituting the filmy corona and the brilliant red prominences, familiar to observers of the totally eclipsed sun. Ordinarily the corona,

FIG. 1.—QUIESCENT SOLAR PROMINENCE 80,000 MILES HIGH
Photographed by Ellerman with the 13-foot spectroheliograph of the Mount Wilson Observatory

whose streamers extend more than a million miles from the photosphere, and the prominences, which in rare cases rise to altitudes of several hundred thousand miles, are hidden from view by the brighter light of the sky around the sun. But when this glare is completely cut off by the moon at a total eclipse, they suddenly become visible.

The spectrum of the prominences was observed by Janssen at the total eclipse of 1868 in India. He found no continuous rainbow band, crossed by dark lines, like that given by the photosphere, but merely three or four bright lines due to hydrogen and a single yellow line, shown later to represent the gas now well known as helium. These lines were so brilliant that he was able to see them after the eclipse was over. Thus arose the method, previously suggested by Lockyer and successfully tested by him just before the news of Janssen's discovery reached Europe, of observing the prominences on any day in full sunlight. By widening the slit of the spectroscope, placed tangent to the edge of the sun, the forms of the prominences can be clearly seen. The most suitable line for this purpose is the red line of hydrogen, with which the prominences appear like brilliant red flames.

Among all the variety of celestial objects none can be found more striking than these. Most of the prominences resemble clouds, which change slowly in outline (Fig. 1). Others are of a very different type, and their forms can be seen to vary from minute to minute. Most spectacular of all are the violent eruptions, which put to shame the greatest outbursts of terrestrial volcanoes. One of these, which rose 120,000 miles in 18 minutes, is shown in Figures 2 and 3.

As the sun rotates upon its axis, the prominences thus observed around its circumference naturally come between us and the disk. In this position they cannot be seen through a spectroscope with widened slit because of the extreme brilliancy of the direct sunlight, so much more intense than the light of the sky. I have recently perfected a simple instrument (the spectrohelioscope) for viewing them against the disk, the principle of which was suggested by Janssen, Lockyer, and Young in the early days of solar spectroscopy. In fact, Professor Charles A. Young, then of Dartmouth College and later of Princeton, built an instrument closely similar to the one now in use in my Solar Laboratory in Pasadena (a branch of the Mount Wilson Observatory). This was used with some success in observing prominences on the sun's circumference, but apparently it was not tried for the purpose of detecting them in projection against the disk. The method was abandoned in favor of the widened slit, when it was shown by Zöllner and Huggins in 1869 that this would suffice to show the prominences against the sky.[1]

The principle involved is easily understood. An image of the sun is formed on the slit of the spectroscope. The hydrogen line Hα, near the red end of the solar spectrum, is like a very narrow window directed toward the sun's disk. The width of this line, and therefore the width of the window, can be increased by opening the slit of the spectroscope, but the delicate details of the prominences projected against the disk are then lost in the resulting glare. This difficulty can be overcome by rapidly oscillating the narrow

[1]Professor Young's original spectroscope still exists in the Dartmouth College Observatory, and at my suggestion Professor Poor is replacing the parts necessary to restore it for use as a spectrohelioscope.

FIG. 1.—QUIESCENT SOLAR PROMINENCE
Photographed by Ellerman with the 13-foot spectroheliograph of the Mount Wilson Observatory

Fig. 2.—Eruptive prominence, 162,000 miles high. Photographed by Ellerman with the spectroheliograph of the Kenwood Observatory at 10h 40m, March 25, 1895

Fig. 3.—The same prominence, 18 minutes later, when it had attained a height of 281,000 miles

spectroscope slit and with it a second slit, which excludes from the eye all light except that of the oscillating hydrogen line. We thus acquire what we may call a hydrogen window, which permits us to observe all the changing phenomena in the hydrogen atmosphere of the sun, both in profile about the circumference and in projection against the disk.

The views thus afforded on any clear day are far too varied to describe within the limits of this article. Some impression of their nature, however, can be obtained from the illustrations (Figs. 4, 5, 6). These are from photographs made on Mount Wilson with the spectroheliograph, an instrument devised by the writer in 1889 for photographing the sun in monochromatic light, and since applied in a long series of investigations. The spectrohelioscope (as I have called the new instrument with oscillating slits) now enables us to *see* all of the hydrogen phenomena in the course of their rapid changes, and not merely to photograph them blindly, without knowledge of what is happening at critical moments, as we have been compelled to do in the past. Moreover, the new instrument, though inferior to the spectroheliograph in some respects, has certain important advantages of its own.

One of these is its instant power of distinguishing between gases moving at different velocities. In fact, our hydrogen window not only excludes from view all solar phenomena except those of the hydrogen atmosphere: it also automatically confines our observations to hydrogen clouds moving at certain velocities.[1] By the turn of a screw in the hand of the observer the velocity limits can be instantly changed, permitting the parts of a prominence which are at rest to be distinguished at once from those that are moving toward or from the earth. This device is of great value in the study of solar vortices, the great whirling storms, like terrestrial tornadoes on an enormous scale, which we discovered on Mount Wilson in 1908 to center above sunspots (Figs. 5 and 6).

As everyone knows, the characteristic storms of the earth's atmosphere are cyclonic in nature, and the direction of the wind in these cyclones is always

[1]Except in cases where the hydrogen line is considerably widened by pressure or other causes.

Fig. 4.—Prominences seen in projection against the sun's disk

such as to correspond to a left-handed or counter-clockwise whirl in the northern hemisphere, and a right-handed or clockwise whirl in the southern hemisphere. Tornadoes are much smaller, but far more violent storms, which whirl in the same direction as cyclones. After discovering similar storms in the hydrogen atmosphere over sun-spots, of a diameter many times that of the earth, we naturally endeavored to learn whether the terrestrial law will also serve to define the direction of whirl in these solar tornadoes.

We at once encountered two difficulties. Sun-spots generally occur in pairs, and the hydrogen structure above the two spots usually indicates opposite directions of whirl. But even if we confine our attention to single spots, our difficulties do not all disappear. The hydrogen pattern above some single spots, like that (in the southern hemisphere) in Fig. 6, unmistakably reveals the direction of whirl, in this instance clockwise, thus corresponding to terrestrial storms. But the interpretation of the structure above the largest spot in Fig. 5 is far less certain. Here the long, slightly curved filamen

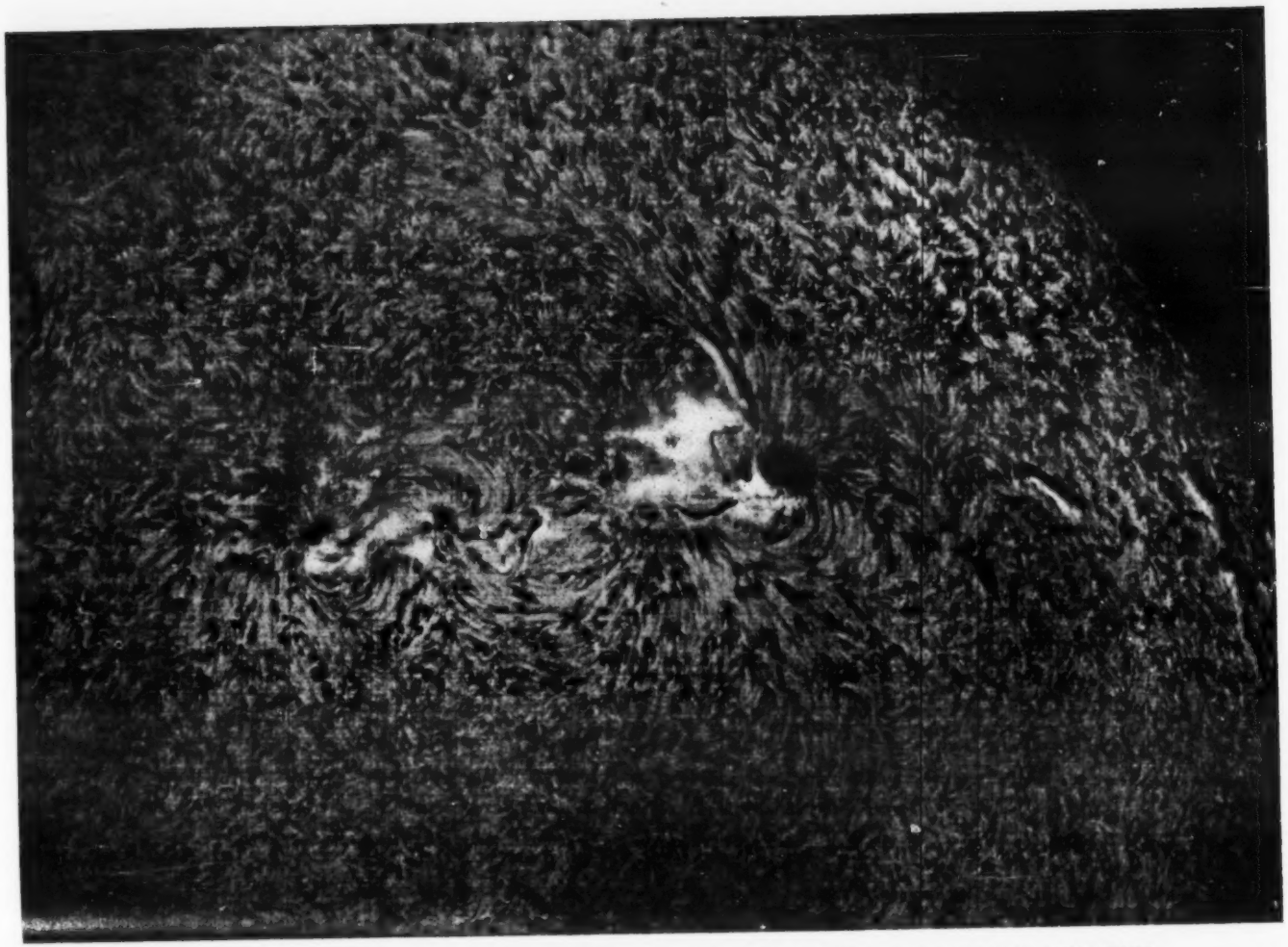


FIG. 5.—HYDROGEN VORTICES OR TORNADOES IN THE SOLAR ATMOSPHERE ABOVE SUN-SPOTS

FIG. 5.—HYDROGEN VORTICES OR TORNADOES IN THE SOLAR ATMOSPHERE ABOVE SUN-SPOTS

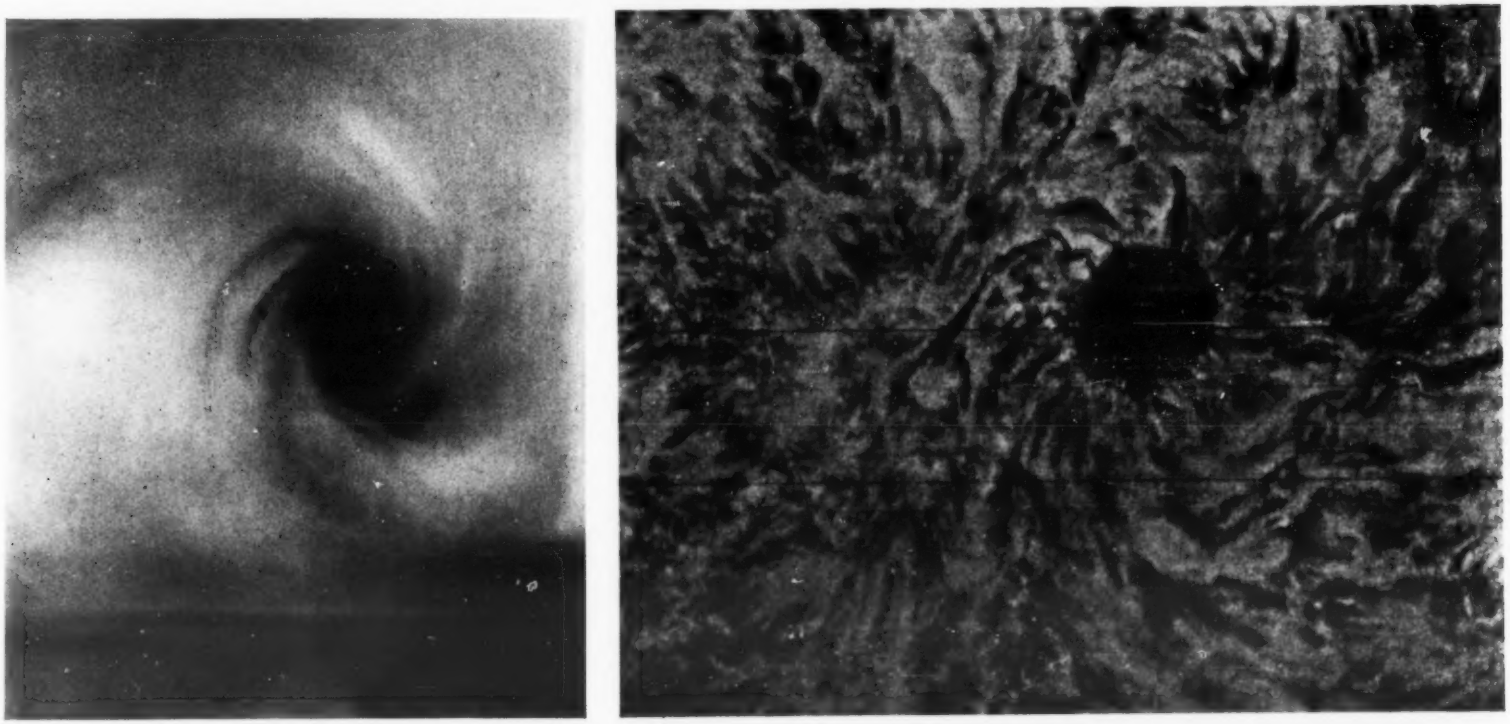


FIG. 6.—(LEFT) A SMOKE VORTEX PRODUCED BY THE METHOD DESCRIBED IN THE TEXT. (RIGHT) HYDROGEN VORTEX IN THE SOLAR ATMOSPHERE ABOVE A SINGLE SUN-SPOT

above the spot (which is in the northern hemisphere) suggests a clockwise whirl, while the vortex structure below the spot is clearly counter-clockwise.

I concluded last year from a study of many photographs that such confusion often results from the presence of two very different classes of phenomena: (1) true vortex structure, where the comparatively cool hydrogen at high levels flows inward and downward toward the spot, and (2), arched prominences, representing hydrogen shot upward from eruptive centers outside the spot, ultimately falling back toward the photosphere after describing a long curved trajectory like the path of a projectile. In such an eruption the hydrogen, when leaving the surface, is so hot that it appears bright against the background. But it rapidly cools as it rises, and the arch which represents the higher parts of the trajectory, though in fact composed of hydrogen so hot that it would appear bright against the sky at the edge of the sun, is cool enough to absorb the light from below and thus seems dark. Evidence of several kinds favors the existence of such eruptive arches, and suggests that the slightly curved filament above the largest spot in Fig. 5 is of this nature. But further proof was needed and this has been supplied, at least in one instance, by the spectrohelioscope. The observation is worth citing, not only because of its value in showing the nature of an interesting class of solar phenomena, but also as an illustration of the power of a newly acquired instrument.

A few days ago (on May 31, 1926) I was observing a sun-spot through the hydrogen window of the spectrohelioscope. I had seen a sharply curved dark filament of hydrogen leading to the spot, recorded its curvature, and had passed on to examine other regions of the disk. At $10^h\,11^m$ I looked again at the spot and was struck by the presence of a brilliant hydrogen outburst near it on the east, which was not visible a few minutes before. Changing steadily in form, the new bright clouds continued to glow brightly for about ten minutes, and then faded slowly. I was then able to see that the curved dark filament had disappeared, as though the comparatively cool mass of hydrogen which it represented had been swept down into the vortex, reappearing at a lower level in the form of the brilliant clouds which had so suddenly come into view. At $11^h\,05^m$ the spectacle was over, though one of the regions near the spot continued to glow less brightly. The nearest parallel to this phenomenon in our daily photographic record on Mount Wilson dates back to June 3, 1908, when a great mass of hydrogen was swept into a spot vortex within a few minutes. This in itself is a good illustration of the value of the spectrohelioscope in rendering visible a phenomenon never seen before. But what followed was even more striking.

In the afternoon, I looked again at the spot and noticed near it a small area still faintly glowing. Then I detected the end of a bow-shaped dark arch, resembling that above the largest spot in Fig. 5. This could not be seen as a whole, but came into view in parts, as the second slit was moved from the violet to the red side of the hydrogen line. A mass of gas coming at high velocity toward the observer shifts the lines in its spectrum toward the violet, and therefore cannot be seen through one of these lines unless the oscillating second slit is displaced toward the violet to receive it. Similarly, in order to see a rapidly receding prominence,

the second slit must be moved toward the red. Thus our hydrogen window has a marvelous power of discrimination, not invariably permitting passage to hydrogen light characterized by the Hα line, but only to such light coming from a source moving in a stipulated direction at a velocity corresponding to the distance of the second slit from the normal center of the line.[1]

Having my hydrogen window under instant control, I could thus see exactly what was happening in the arch. The hydrogen was shooting upward (seen with slit to violet) from the point near the sun-spot, moving along the higher part of the trajectory nearly parallel to the solar surface, and therefore nearly normal to the line of sight (slit central), and descending rapidly at the farther end of the arch (slit to red). The nature of the arch was clear, and the distinction between it and the vortex structure unequivocal.

Mount a vertical shaft in a small glass tank half full of water, bearing a paddle (a flat piece of brass or a quarter inch twist drill) almost reaching the surface. Spin the shaft with an electric motor, and a vortex will be produced in the water. By proper adjustment of the paddle, the flow will be upward and spirally outward along the surface. This is our artificial sun-spot. Cover the tank with a sheet of glass and fill the space above the water with smoke, which must not be too dense or too uniformally mixed.[2] Spin the paddle and illuminate the smoke with sunlight through a horizontal slit in a sheet of cardboard covering one side of the tank. Look down into the smoke through the cover of the tank and a beautiful smoke vortex will be seen, closely resembling the hydrogen vortex above a sun-spot (Fig. 6). By moving the slip up and down, cross sections of the vortex can be observed at different levels. When the slit is placed in a vertical position, a vertical section of the vortex can be seen through the side wall of the tank. If two paddles are used, rotating in opposite directions about three quarters of an inch apart, the characteristic vortex structure often photographed in the solar atmosphere above double sunspots can be approximately imitated.

After a long study of solar vortices, utilizing the daily photographs made with the spectroheliograph on Mount Wilson since 1908, and taking into account our daily observations of the magnetic fields in sun-spots and the valuable investigations of Evershed and St. John on the motions of the gases above spots, I believe that these smoke experiments give a very good idea of what actually happens in the sun.

When we first discovered the hydrogen vortices in 1908, I inferred that they pointed to the vortical nature of sun-spots and the probable existence within them of magnetic fields. The reasoning was simple A magnetic field is produced in the laboratory by an electric current flowing through a coil of wire. If, in harmony with modern physics, free electrons could be assumed to be present in the hot gases of the sun, a whirling mass of them in a sun-spot vortex should set up a magnetic field. If sufficiently intense, such a field should split the lines in the spectrum of the spot vapors into two or more components, exactly as the same lines are split in the laboratory when

[1] This method is most effective in the case of the rare hydrogen at high levels, which usually gives a very narrow dark Hα line. The hot hydrogen rising from lower levels gives a wider bright line, but its velocity in the line of sight can often be measured with the spectrohelioscope by determining the position of its maximum of intensity.

[2] To obtain smoke slowly entering through a small brass tube like an inverted L, its horizontal member perforated with small holes and supported about two inches above the water and the same distance to one side of the shaft, will serve very well.

these vapors are observed between the poles of a powerful magnet (the Zeeman effect). The components are polarized in a distinctive way, so that one or the other can be cut off by a Nicol prism and quarter-wave plate. Thus the existence of magnetic fields in sun-spots should be unmistakably recognized.[1]

law of sun-spot polarity.[2] (Fig. 7).

The typical sun-spot consists of two spots or group of spots, one of north polarity, the other of south polarity, the axis of the pair usually making only a small angle with the sun's equator. From day to day the spots are carried westward across the solar disk by the sun's axial rotation. During

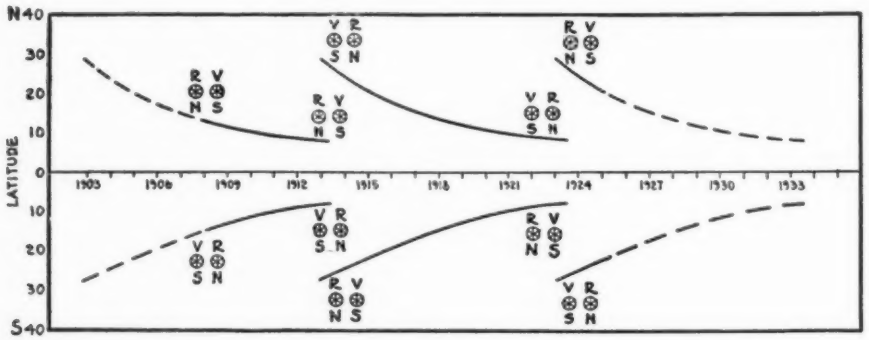


Fig. 7.—The law of sun-spot polarity. The curves represent the approximate variation in mean latitude and the corresponding magnetic polarities of spot groups observed at Mount Wilson from June, 1908, to January, 1925. The preceding spot is shown on the right

The immediate application of this test revealed all the characteristic phenomena of the Zeeman effect, and demonstrated the presence of a magnetic field in every spot examined. It also proved to be an easy matter to determine the polarity (north or south) and intensity of each of these fields. Thus it became possible to undertake on Mount Wilson a systematic study of the magnetic properties of sun-spots. The 150-foot tower telescope is used daily for this purpose, and each spot in every spot-group present on the sun is examined with the 75-foot spectroscope. In this way the polarities and approximate field-strengths of the members of about 2200 sun-spot groups were recorded between 1908 and 1925. A study of these results has yielded the

the 11½ year sun-spot cycle beginning in 1901 the leading (western) spots in the northern hemisphere were found to be of south polarity, while the leading spots in the southern hemisphere were of north polarity. As usual, the spots gradually increased in number from the minimum in 1901, reached a maximum a few years later, and gradually decreased in number until the minimum in 1912. Meanwhile their average latitude steadily decreased, the last spots of the cycle appearing near the equator.

The beginning of a new 11½ year cycle is marked by the sudden appearance in both hemispheres of spots in comparatively high latitudes. To our surprise, these new spots were opposite in polarity to those of the preceding

[1]Although the magnetic fields are certainly present, the problem is less simple now than it seemed in 1908, because of the difficulty of accounting for the strong electric currents necessary to produce such intense fields.

[2]See Hale and Nicholson, "The Law of Sun-spot Polarity": Contributions from the Mount Wilson Observatory, No. 300; *Astrophysical Journal*, Vol. LXII, pp. 270–300, 1925.

cycle, i. e., the leading spots in the northern hemisphere were now of north polarity instead of south, while those of the southern hemisphere were of south polarity instead of north. Moreover, as the spots of the new cycle begin to appear in high latitudes about two years before the last of the spots of the old cycle disappear near the equator, there changes of circulation, still beyond the range of both observation and theory, within the body of the sun. The hydrogen vortices in the solar atmosphere, though apparently set up by the effect of the underlying spot vortices, nevertheless seem to follow the law of terrestrial storms. At least, the great majority of those above single

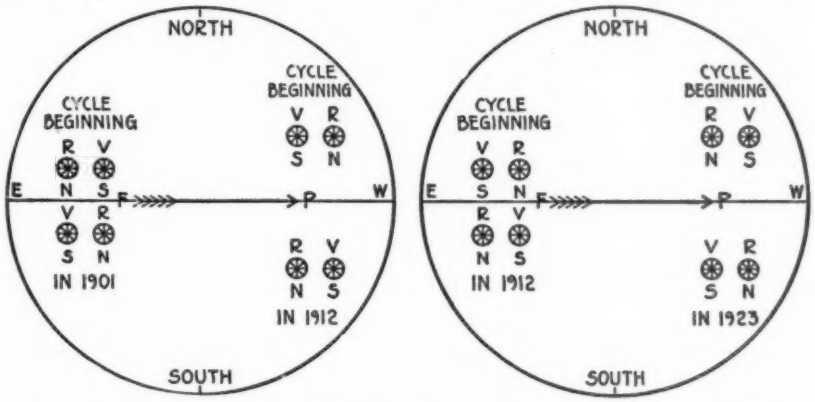


Fig. 8.—Sun-spot zones during the minimum of solar activity. Two zones in each hemisphere, in which the spots are of opposite magnetic polarity, exist for about two years at the time of each sun-spot minimum

is a period during which the sun exhibits two zones in each hemisphere, in which the spots are of opposite magnetic polarity (Fig. 8).

Without going into further details, it may be considered probable that the electric current that produces the magnetic fields in sun-spots is always of the same sign, either positive or negative. If so, the reversal of polarity which we have now observed at two consecutive sun-spot minima, those of 1912 and 1923, must mean a reversal in the direction of whirl in the great tornadoes which constitute the spots. Thus the law of storms at the level in the sun where spots are formed is far more complicated than the terrestrial law, and probably points to recurrent spots correspond with terrestrial storms in direction of whirl, and show no tendency to reverse this direction at sun-spot minima. There is no theoretical difficulty about this, as Bjerknes has shown. Even in a small tank of water, it is possible to maintain for some time a clockwise or counter-clockwise vortex at the surface by means of a paddle whirling in the opposite direction a few inches below.

The broader bearing of the results mentioned in this article are easily recognized. They suggest a curious law of circulation within the sun which orginated in an earlier period of its career and must also operate in many other stars at a similar stage of development.

GIANT SPIRAL NEBULA, MARCH 23, 1914

Illustrating a distribution of matter similar to that assumed to have characterized the material out of which, according to the planetesimal hypothesis, the solar system was made. It is assumed that in the course of time, the central mass became the sun and that other denser knots of planetesimal matter were collected to form the planets which still occupy outlying positions.

Photograph from the Lick Observatory

Early History of the Earth

By CHARLES P. BERKEY

Research Associate in Geology at the American Museum; Professor of Geology at Columbia University

TO an inhabitant of Mars the earth would look like any other planet; from a real star it could not be seen at all. Yet it is close kin to the stars,—the offspring of one of them, the sun, almost too insignificant to notice except for the momentous fact that it happens to be the place where the human race lives. On this account, the earth, its origin and history, is of special interest to us.

Although it is the geologist's task to read the history of the earth, he has to admit that the early part of it is almost hopelessly beyond his reach. Compared to the stars, the earth must be quite young, yet its readable history indicates an existence of hundreds of millions of years. There may be myriads of similar bodies associated with the other stars. It hardly seems reasonable that our sun should be the only one to be accompanied in this way by bodies in some respects like our earth.

It may be, of course, that some very unusual happening was responsible for the earth and the other planets of our solar system. They may mark an accident that almost wrecked it. Astrophysicists say that if two suns were to approach each other near enough, the ordinary stability due to gravitation would become so deranged that the one with less mass would explode. Great streamers of disrupted matter would be expelled as the bodies pass each other and would become separated into particles and scattered to prodigious distances. It is claimed that such an accident would not necessarily destroy the whole sun in this manner, or utterly scatter the ejected material beyond control, but that a comparatively large mass would still be left as a central sun, around which the expelled matter would continue to revolve. One must visualize, therefore, a central sun, part of whose original material has been expelled and cooled to become planet dust, occupying the surrounding space to as great distance as the farthest planet, and moving under the control of the sun itself.

Then the work of building begins—the building of planets out of the explosion débris, for, in this view, the earth was not made out of nothing, no matter what can be said of the stars, but directly out of substantial physical material, every particle of which was gathered up from the swarm of fragments revolving around the sun. These particles, no matter how large or small, had their own orbits, differing somewhat one from another, but each following a course as orderly and as definitely under the control of gravitational law as the earth follows today. These are the so-called planetesimals of Chamberlin.

With the myriads of planetesimals, all belonging to a single revolving system, there must be attractions also among themselves. Gravitation is universal. All bodies exert a gravitational pull on all others, and the more massive a body is the more gravitational power it exerts. The tendency is for them to be drawn together with many collisions since they are all moving around the central sun in the same general direction. Under such condi-

tions it is held that the larger planetesimals would grow by accretion. The smaller planetesimals would be gathered up gradually, one at a time, year after year, century after century, age after age, until the sky was swept clear of them.

Thus a few large masses built up by smaller planetesimals came into existence. Among them was the earth and its satellite, the moon. The earth grew by addition of planet dust, or sun matter, from a much smaller size to its present proportions. Thus it had a history of growth before its history as the finished earth began. At its birth and while it was small, it was quite incapable of supporting many of the activities that are now characteristic of it such as those depending on atmosphere, and water, and life. So it grew, slowly, to greater and greater competence until, after millions upon millions of years, it finally became great and stable enough to be the scene of one of the great cosmic happenings,—the introduction of life and the evolution of organisms.

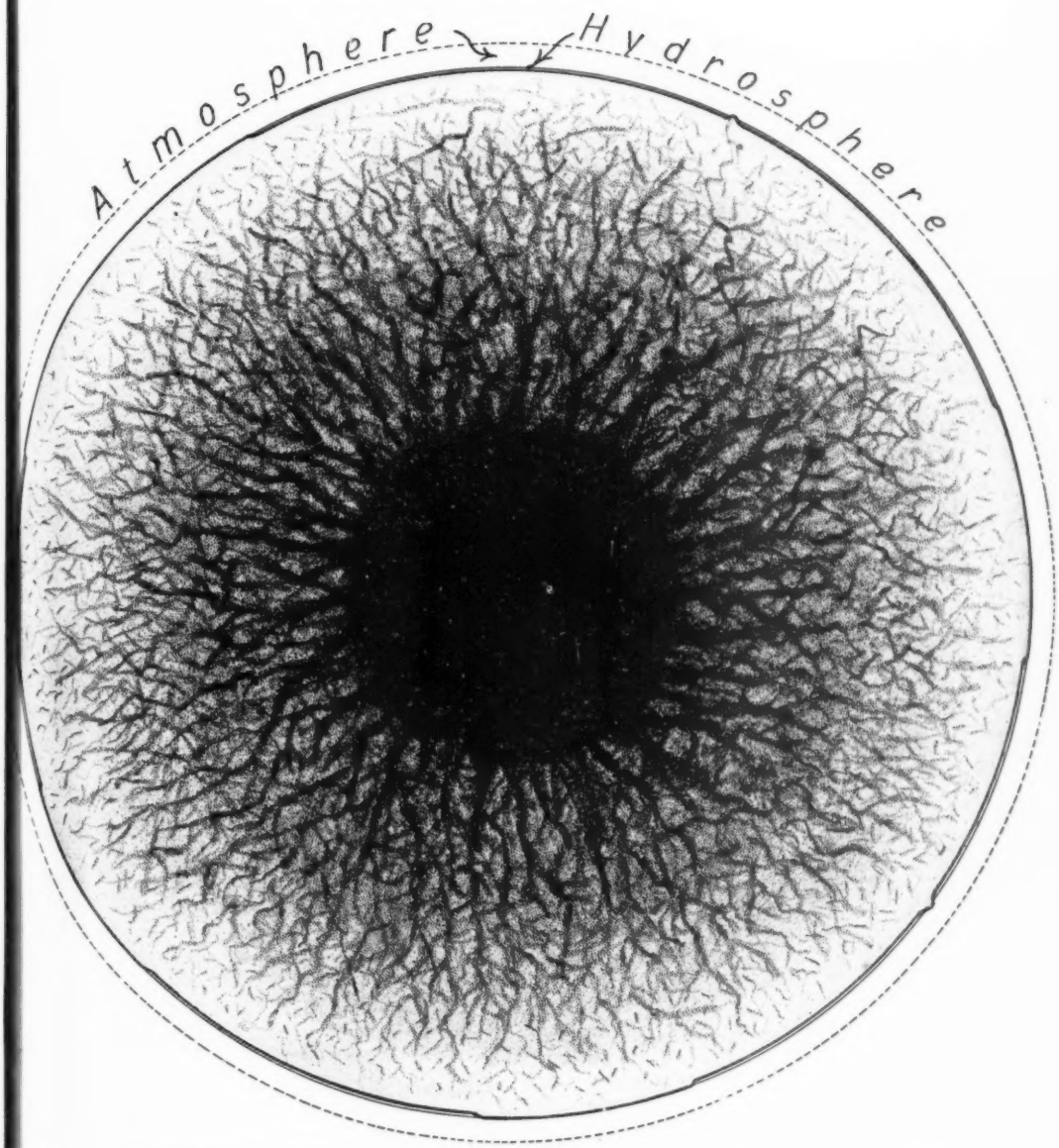
There are, of course, other hypotheses of the origin of the earth. The nebular hypothesis of La Place is older than the planetesimal hypothesis of Chamberlin and in some respects a little simpler. It postulates an enormously extended hot gaseous mass which in the course of time condensed and contracted and separated into rings and finally formed the solar system. Under this hypothesis, the earth passed through a gaseous, then a liquid stage, and finally by cooling reached a solidifying stage with the formation of a crust and a molten interior. Long cooling has made it more stable.

There are minor modifications of both hypotheses, and there are supporters of all of them, but perhaps it is fair to say that most geologists find some form of planetesimal hypothesis of earth origin more satisfying than the other type.

The original heterogeneity of composition, due directly to growth by addition of particles, would make an earth with heavy and light material mixed throughout the mass. It would also bring quite unlike materials together into close contact where their native tendencies to reaction could operate. Thus a series of reactions and processes were inaugurated, the end of which will not be reached until the substance of the whole earth is reduced to essential stability. It may be that this original heterogeneity is chiefly responsible for its long dynamic history. Indeed it may have been the mainspring that has kept the internal processes going and has made the earth almost a live thing to the present day.

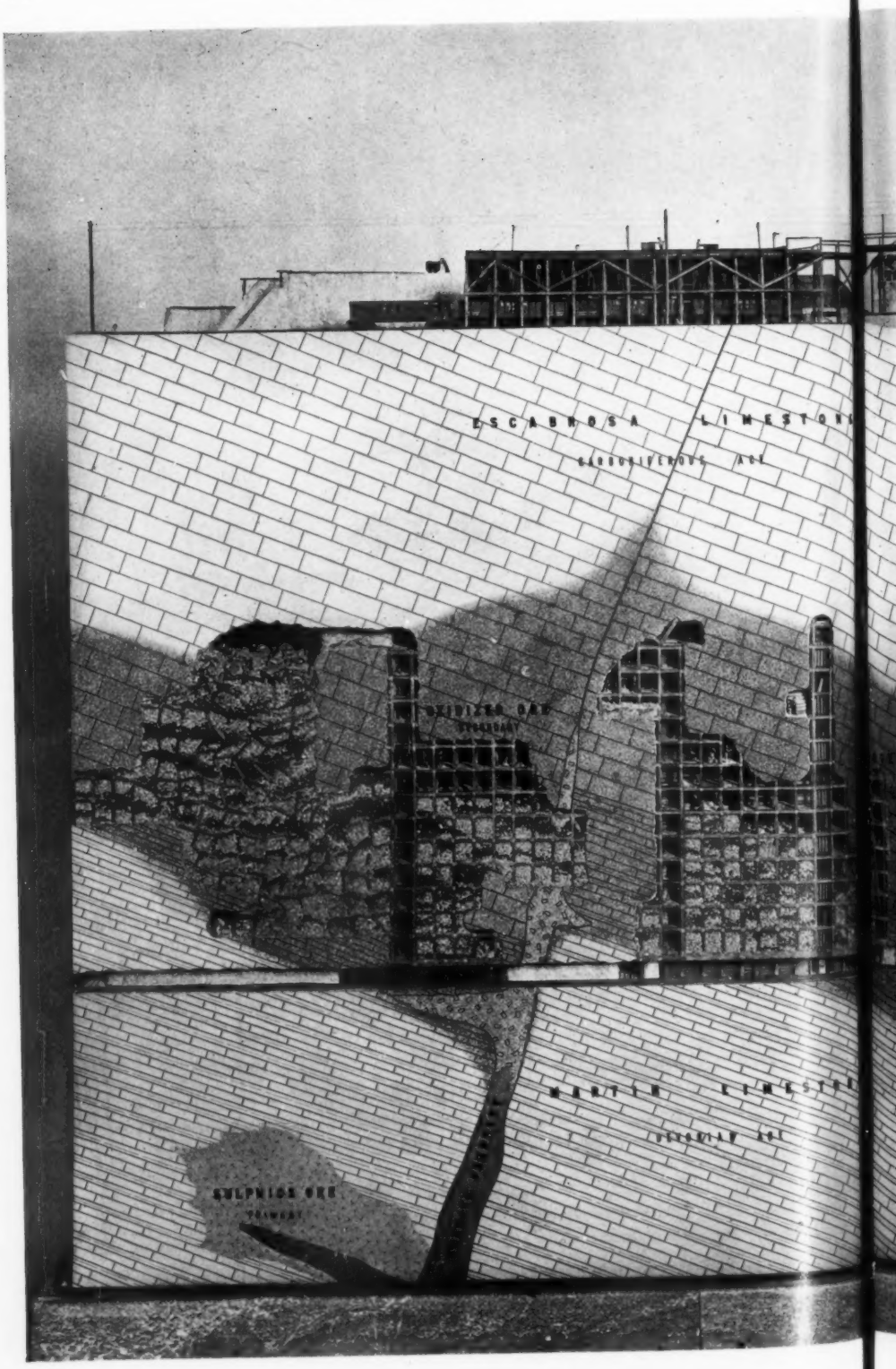
Geologists who regard the earth in this way think of it as undergoing profound internal changes in the course of which many substances have been formed that were not present on the surface in the beginning. Some of these are of immense importance in the economy of life, such as water and air.

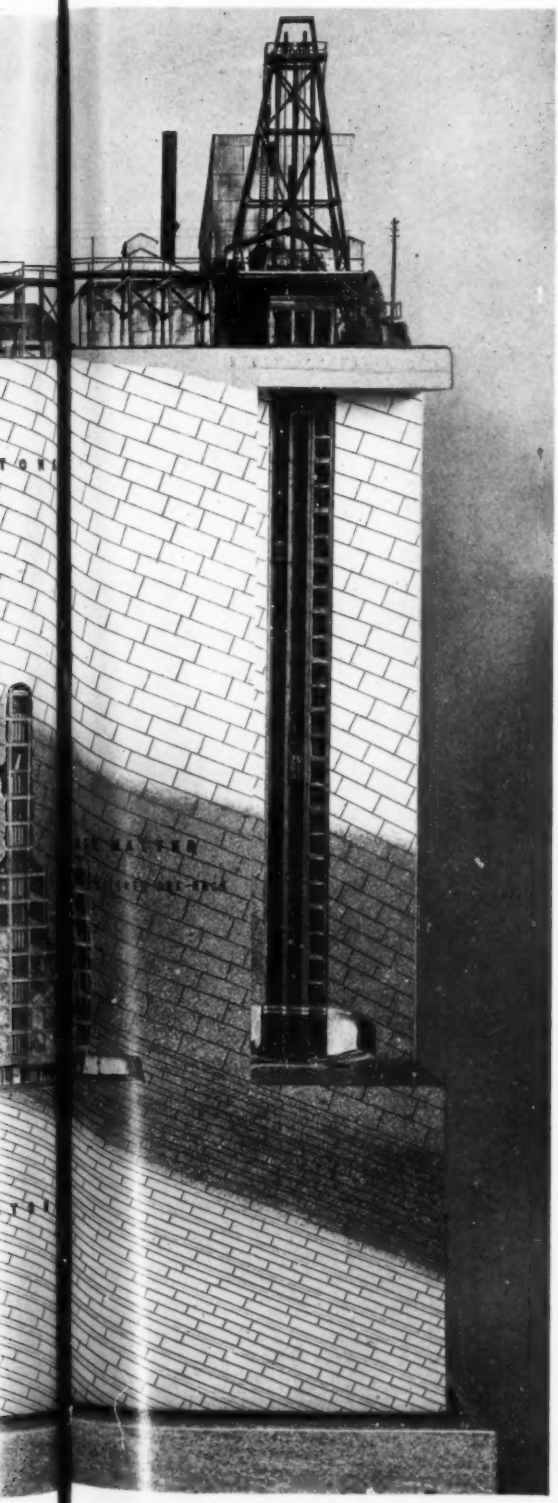
The original porous mass has become much condensed and essentially solid. Physical crowding, due to weight and gravitation, aided by chemical reaction, caused portions to fuse and thus molten rocks were produced and volcanism became established. Probably every portion of the original earth matter has been repeatedly fused and solidified again, but not all portions at the same time. By means of these repeated fusions the substances of the earth have been reorganized and its elements redistributed, the heavier substances settling down toward the



A CONCEPTION OF THE ZONAL CHARACTER OF THE INTERNAL STRUCTURE OF THE EARTH

Following Dr. Henry S. Washington's suggestion and the generally accepted judgment of geophysicists that the central portion is made up largely of metallic substances, probably iron alloyed with nickel, and that the outermost zone is stony, making the rocks that we know more about, while the intermediate zone carries a mixture which becomes more heavily metallic in depth and more stony and non-metallic in the higher levels. According to the planetesimal hypothesis, this zonal condition has resulted from a much more mixed distribution of constituents through a long series of earth transformations under the control of gravitation


ESCABROSA LIMESTONE
CARBONIFEROUS AGE
OXIDIZED ORE
SILURIAN
SULPHIDE ORE
PRIMARY
MARTIN LIMESTONE
DEVONIAN AGE



center and the lighter ones rising to become a part of the outer shell. Thus, the earth has become zonal, with the heavy material largely concentrated in the central portion.

Of course, internal reorganization of material commenced as soon as the earth began to grow and has been in progress ever since. As the earth grew to larger and larger size, it took on the physical behavior that we know and that has been so important a factor in its readable geologic history. A very small earth would not have gravitational pull sufficient to hold light gases in control and maintain an atmosphere. Such a condition is even now represented by the moon. But the earth came, by and by, to have mass enough to retain an atmosphere, produced and freed through the reactions of the interior. By and by, also, water was formed and rose to the surface, filling the interstitial spaces between the fallen particles. Ultimately there was so large an amount that it filled the lowest depressions in the surface, and these areas have increased in size until now nearly three-fourths of the surface of the earth is covered with water.

Heat is one of the products of such reorganization as the earth had to go

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MODEL OF THE COPPER QUEEN MINE, BISBEE, ARIZONA

Prepared by the late Dr. E. O. Hovey for the American Museum of Natural History

The general surface features are shown with location of the mine shaft and the position of some of the underground workings. In the foreground, the earth is shown as if cut open so that the underground relations can be seen. The ore body is in the overlying sedimentary rocks where it has been introduced by the upward moving mineral-bearing solution derived from the igneous mass beneath, thus showing the intimate relation between mineralization and volcanism

A VIEW IN THE GRAND CAÑON IN ARIZONA

A trench, nearly a mile deep, has been excavated by the Colorado River, exposing a magnificent section of sedimentary strata and representing several different geologic ages. The lowest of these formations must date back to near the beginning of life. All known fossil-bearing strata throughout the earth are younger than the base of this column in the Grand Cañon. Only a portion of the entire history is represented here, but that is made up by combining the data of many similar sections. V, Archeozoic (Vishnu schist); U, Proterozoic (Unkar formation); T, Ba, M, early Paleozoic; R, Ss, Ssh, C, late Paleozoic. (The figure chosen here is the one used as a frontispiece in *A Textbook of Geology*, Part II.

through. Early in these formative stages, volcanism was inaugurated through the development of heat in the depths of the earth. Then began the long train of processes that depend on molten rock,—out-pouring lavas, volcanic outbursts, and escaping gases that have been in operation ever since.

Volcanism also set free some of the volatile substances of the interior, which escaped to join the accumulating atmosphere and water of the surface zone. On their way to the surface through other rocks, these escaping gases and mineral-bearing solutions left a trail of effects that is of special interest in itself, for in this manner many of the ores of the metals first found a place in deposits rich enough for mines. Of course, this process has kept on to the present time so that there are deposits of all ages.

As soon as the earth came to have an atmosphere and water, an immensely important train of surface processes was inaugurated, beginning with the weathering and decay of rocks, followed by erosion, and ending with deposition of sediments in beds that later hardened into rock again. It is this series of processes more than any other that is responsible for the long story connected with sedimentary strata, which became the cemeteries for the organisms that represent the life history of the earth. Thousands upon thousands of feet of such fossiliferous sediments have been formed. These formations are so important in the later history of the earth with its ever-increasing complexity of life that it is easy to get the impression that earth history began with them. On the contrary, probably when the earth began, it was a comparatively small body having none of the external features that we now know. More time was represented in the accumulations that then helped to build the earth to its present size and form than in all its subsequent history. This early history is largely speculative because the records are almost wholly destroyed by later changes; but it is of fundamental importance that the earth came through such transformations to the stage that we know more about, else we should probably not have an earth so beautifully suited to the uses that have been made of it.

Finally, in the fullness of time, after the atmosphere and the waters were produced, poured out from the earth's own internal laboratories, and the lands and the seas had separated, and some of the present surface conditions were established, there came a day when a new entity appeared. How it happened no one knows. Why, no one can tell any better than he can tell why the earth itself or the stars came to be. Just when it happened is quite impossible to say, but it is certain that after ages, during which there was no life on the earth, there came a day when life appeared. There was a tiny living thing in the waters of the deep. The most momentous step of all was thus taken, for from this obscure beginning a wonderful train of results has been evolved. From it and its kind has come that long line of living things known as animals and plants. Each succeeding epoch saw advancement to greater complexity and competence, each new step apparently growing out of the preceding one, in a strikingly orderly and persistent manner, so that one who follows the story from its beginning to its conclusion can hardly escape the conviction that the whole series is genetically related. The conclusion seems inevitable that in some way which we do

A trench, nearly a mile deep, has been excavated by the Colorado River, exposing a magnificent section of sedimentary strata and representing the base of this column in the Grand Canyon. The lowest of these formations must date back to near the beginning of life. All known fossil-bearing strata throughout the earth are younger than the oldest of these formations. Only a portion of the entire history is represented here, but that is made up by combining the records from the entire world. Archæozoic (Vishnu schist); U. Proterozoic (Unkar formation); P. Pm. M., early Paleozoic; Sh, Sah, C, late Paleozoic. (From descriptions here cited as one used as a frontispiece in *A Textbook of Geology*, Part II.

not fully understand the later and higher forms of life have been evolved from the earlier and simpler ones.

With this part of the story we are not now concerned. It is enough to see its beginning. Two or three hundred million years ago, after the earth had passed through its formative stages to comparative stability, it became a fit place for living things. Thus, in due time, the earth became the home of Man.

Born of the stars, formed of star dust, and nourished by sunlight, the earth has undergone a metamorphism so severe that there is probably not a particle of the original material left in its primitive condition. It has been entirely remade. The whole mass has been molded into form and its original potential energy has run down to comparative stability. So it has become possible for the earth as a wonderful mother to preserve and nourish the delicate thing that was first life, and transmit, undiminished and in manifold form, the vital spark that is the glory of the organic world.

TABULATED STAGES IN THE HISTORY OF THE EARTH

THE FORMATIVE ERAS

covering an enormously long time.

(Almost no records; history largely speculative, based on inferences.)

1. The nuclear stage, when the earth was small
2. The atmosphereless stage
3. Initiation of volcanism
4. Development of atmosphere and water
5. The establishment of oceans and continents

THE ADVENT OF LIFE

THE ERAS OF LIFE

from little known to well known times, covering probably a thousand million years.

(Geologic records more and more complete; history based on interpretation of earth structures and forms of life.)

6. The Archæozoic Era (dawn life)
7. The Proterozoic Era (primitive forms of life)
8. The Palæozoic Era (ancient forms of life)
9. The Mesozoic Era (intermediate forms of life)
10. The Cenozoic Era (modern forms of life)

Ancient Concepts of the Universe

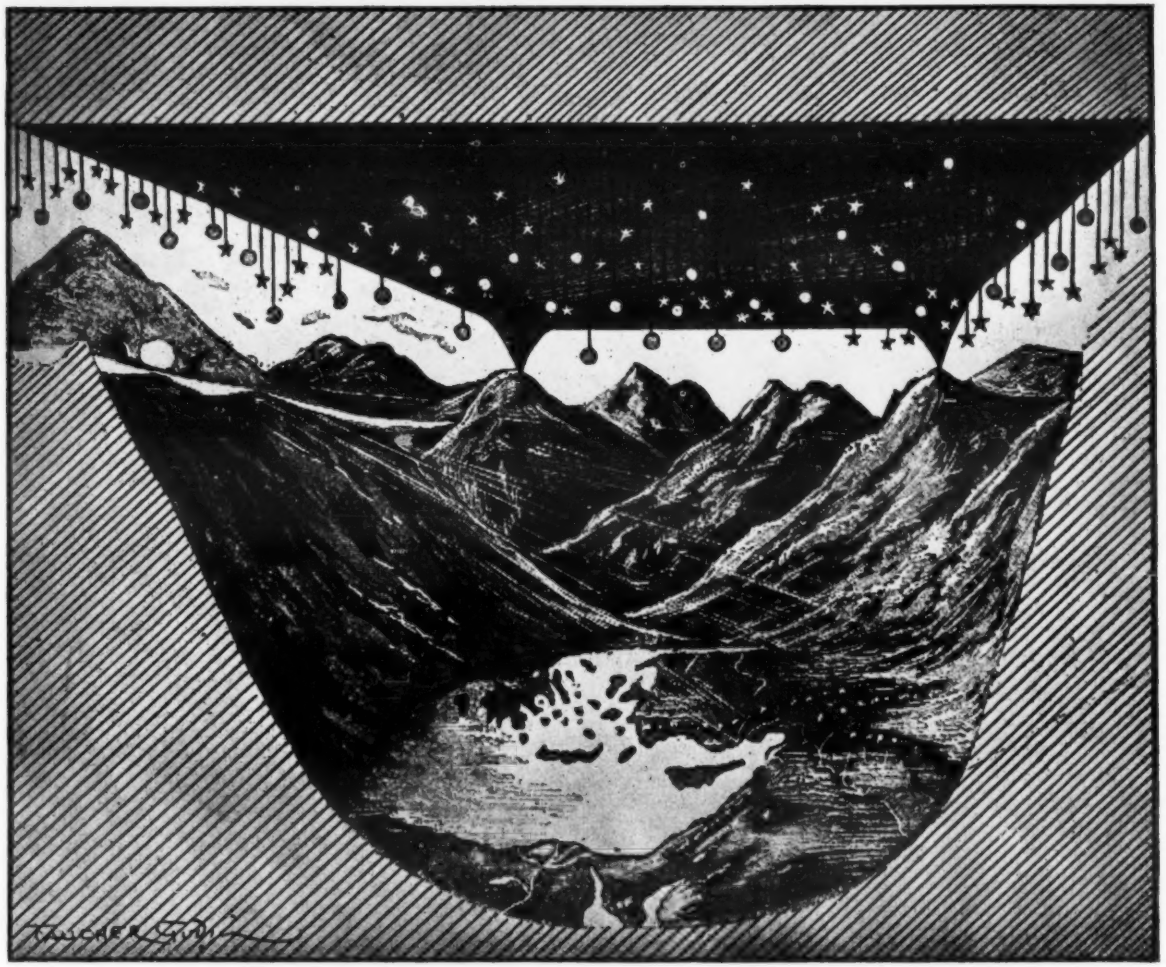
THAT astronomy is as old as civilization is well authenticated by the records of the science among early nations. According to the Greek historians, the earliest traces of astronomical science were found among the ancient Chaldæans and Egyptians, and Maspero in his *The Dawn of Civilization—Egypt and Chaldæa* gives two interesting accounts of the structure of the universe as imagined by these peoples. The following excerpts, together with the illustrations on pp. 384–85 describe graphically their respective beliefs.

AN ATTEMPT TO REPRESENT THE EGYPTIAN UNIVERSE

The Egyptians "imagined the whole universe to be a large box, nearly rectangular in form, . . . The earth, with its alternate continents and seas, formed the bottom of the box; it was a narrow, oblong, and slightly concave floor, with Egypt in its center. The sky stretched over it like an iron ceiling, flat according to some, vaulted according to others. Its earthward face was capriciously sprinkled with lamps hung from strong cables, and which, extinguished or unperceived by day, were lighted, or became visible to our eyes, at night. . . . The sun was a disc of fire placed upon a boat. At the same equable rate, the river carried it round the ramparts of the world. From evening until morning it disappeared within the gorges of Daït, its light did not then reach us, and it was night, . . . "

THE WORLD AS CONCEIVED BY THE CHALDÆANS

"As in Egypt, the world was a kind of enclosed chamber balanced on the bosom of the eternal waters. The earth, which forms the lower part of it, or floor, is something like an overturned boat in appearance, and hollow underneath, not like one of the narrow skiffs in use among other races, but a kufa, or kind of semicircular boat such as the tribes of the Lower Euphrates have made use of from the earliest antiquity down to our own times. The earth rises gradually from the extremities to the centre, like a great mountain, of which the snow-region, where the Euphrates finds its source, approximately marks the summit. . . . Near the foot of the mountain, the edges of the so-called boat curve abruptly outwards, and surround the earth with a continuous wall of uniform height having no opening. The waters accumulated in the hollow thus formed, as in a ditch; it was a narrow and mysterious sea, an ocean stream, which no living man might cross save with permission from on high, and whose waves rigorously separated the domain of men from the regions reserved to the gods. The heavens rose above 'the mountain of the world' like a boldly formed dome, the circumference of which rested on the top of the wall in the same way as the upper structures of a house rest on its foundations. . . . He [Merodach] left it quite solid in the southern regions, but tunnelled it in the north, by contriving within it a huge cavern which communicated with the external space by means of two doors placed at the east and the west. The sun came forth each morning by the first of these doors; he mounted to the zenith, following the internal base of the cupola from east to south; then he slowly descended again to the western door, and re-entered the tunnel in the firmament, where he spent the night. . . . "



AN ATTEMPT TO REPRESENT THE EGYPTIAN UNIVERSE

Section taken at Hermopolis. To the left is the bark of the sun on the celestial river. From Maspero's *The Dawn of Civilization*

AN ATTEMPT TO REPRESENT THE EGYPTIAN UNIVERSE

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THE WORLD AS
CONCEIVED BY THE CHALDÆANS
From Maspero's *The Dawn of Civilization*

Island Universes

By W. J. LUYTEN
Of the Harvard College Observatory

"He is no longer a slave who can choose his master"—Henri Poincare

INASMUCH as universe means ALL, it is perhaps a little difficult to understand its use in the plural. By a change of meaning which is as intelligible as it is illogical, universe, to the astronomer, is now limited to meaning all that was once thought to exist, instead of what really does exist. When the astronomer speaks of "other universes," he is not guilty of megalomania, nor should he be accused of usurping the divine prerogative. To the man of science the term "other universes" simply indicates that the material reality of present-day astronomy has far surpassed our original conception of the universe. What, fifty years ago, we thought of as *the* universe, has now been demoted to the rank of *a* universe, merely one out of many. With one stroke of the pen, the spiral nebulæ have been given their freedom—they are no longer of an inferior order in the Milky Way but free and independent citizens of the Cosmic Commonwealth—Island Universes.

The "eternal silence of infinite space" which so frightened Pascal has ceased to exist for us. We see space aglow with light-messages from numberless universes, we are seeing their history, looking into their past—which may be our future.

From the anthropocentric world-conception of primitive man to the modern ideas about island universes is a long step, and one which has taken time. Ever since the beginning of science our measurements have progressed in two directions—toward the infinitely small and toward the infinitely great. In daily life we measure in inches, feet, and miles. When we are measuring light waves in the laboratory, we descend to microns, or thousandths of a millimeter. X-rays make us use Ångstrom units, of the order of one-billionth of an inch. When we speak of electrons and protons, we are thinking of material bodies a quadrillionth of an inch in size. The astronomer, although he uses these small units in his analysis of the light of the stars and studies the behavior of the electrons and protons throughout the cosmos, finds that he must extend the longest units because they are far too short for him. The moment we leave the earth behind us and consider the solar system, we are dealing in millions of miles and begin by calling the distance sun-earth, 93,000,000 miles, *one* astronomical unit. Outside the solar system, for distances between stars, this unit, too, becomes insignificant: the nearest star, Alpha Centauri, is almost three hundred thousand astronomical units away. While looking for larger yardsticks with which to fathom the depths of the cosmos, we naturally think of calling in the assistance of light, with its tremendous speed of 186,000 miles a second. And we adopt as a new unit in the stellar universe, a light-year, the distance traveled by a ray of light in one year, and equal to about five trillion miles. For the nearer parts of space this light-year is a convenient unit; Alpha Centauri is now 4½ such units distant, Sirius about 10, the Pole

Star 200, the Orion nebula about 500. A sphere with the sun at its center and a radius of one thousand light-years would take in most of the stars we can see with the unaided eye. Twenty-five thousand light-years would reach practically all the stars in our Milky Way system; the globular clusters would still lie outside it. But in order to reach the island universes we must go to millions of light-years, distances great enough to suggest the adoption of a new unit, equal to one million light-years, a light-æon. For the present at least one thousand light-æons would suffice to measure the distance of all known objects, of all island universes.

The existence of nebulæ had been known for centuries, even before the invention of the telescope, and nebulæ have always been the object of much speculation. We may say, however, that the new era of island universes was inaugurated in 1845. Its beginnings were very humble and small; at first there was just Lord Rosse's discovery that a nebula in the constellation Canes Venatici showed a spiral shape. Gradually, as telescopes grew larger, and especially as photography, that most powerful ally, was introduced into astronomy, reinforcements arrived, spiral after spiral was discovered and joined the ranks until at present spiral nebulæ form a well-recognized class of celestial objects. Not only that, they are also very numerous in some parts in the sky, as in the constellations Coma Berenices and Virgo, where a long-exposure photograph may show many hundreds of them on one plate.

For some time astronomers speculated about the nature of these spirals. Were they gaseous, like the Orion nebula, or were they great aggregations of stars, only appearing nebulous on account of their enormous distances? The spectroscope soon put an end to this uncertainty; the Orion nebula proved to be a genuine nebula, composed of incandescent gases, the spiral nebulæ were clearly conglomerations of stars. Long before we knew anything about the distance or the size of these spirals, long before we could distinguish the individual stars in them, the spectroscope had shown us that the behavior of atoms and electrons in these far distant systems was the same as in the stars and on earth,—an apt illustration of the power of spectroscopic methods. One might almost be tempted to say that at these infinite distances we can study only the infinitely small. *Les extremes se touchent.* The next difference of opinion arose about the size and the distance of a spiral. Was it an object comparable in size to the whole Milky Way, or was it simply a good-sized star cluster? Easton, of Holland, a supporter of the former alternative, went so far as to propose a spiral structure for our own Galaxy. On the other hand, a strong argument in favor of the small size of the spirals was afforded by the quick rotation measured in some of the larger specimens. Evidence more certain yet was derived from the new stars which had been observed to flash up in the spiral nebulæ, and from the variable stars which have been discovered in two of them during the past five years. From the reasonable assumption that the new stars in spirals are comparable to similar objects which appear in the Milky Way, Lundmark and Curtis came to the conclusion that the spirals must be millions of light-years away. This conclusion, which was confirmed by Hubble from observations of the variable stars in the spirals, afforded a much more decisive means of estimating the distance. It is now univer-

sally accepted that the spiral nebulæ are millions of light-years distant. The angular size under which they appear to us then indicates that they must be tens of thousands of light-years in size, large enough to merit the name "island universes." The latest edition of the social register of the Cosmos includes, therefore, all these spirals as full-fledged universes entitled to all rights and privileges of a universe.

As for the rotation of spiral nebulæ, the great distances recently derived have made rapid rotation impossible, and the quick internal motion measured some years ago is now universally regarded as an optical illusion. Although it is obvious from a mere inspection of the structure of spirals that they must be rotating, it is inconceivable that they should revolve so rapidly as to make one complete turn in eighty-thousand years. The large linear dimensions indicated by the present-day distances of millions of light-years would result, for the outlying portions of the spirals, in a speed greater than that of light. Such a thing was immediately condemned as unconstitutional; the modern constitution of the cosmos, the doctrine of relativity, does not permit any material object to move faster than light. Consequently the speed of rotation of spiral nebulæ has been assigned an upper limit; one revolution in a million years or more is all that is allowed them.

The best known of all island universes is undoubtedly the Andromeda nebula, a great spiral, just one million light-years away, and about fifty thousand light-years in diameter. It contains millions and possibly billions of stars, the vast majority being too faint to be seen individually. The only stars we can see are thousands of times brighter than the sun, indeed, the sun could not possibly be seen or photographed at a distance of a million light-years.

During the time that the Andromeda nebula has been under observation, a great number of new stars have been seen to appear in it. The first one to be observed burst out in 1885; it reached the seventh magnitude, which means that, in reality, it was one hundred million times brighter than the sun, one tenth as bright as the whole Andromeda universe! During the few days of its maximum splendor it reigned supreme in the cosmos, it was the brightest star we have ever observed. It was also the most wasteful, for at that time it was radiating so much light and energy into space that, according to the theory of relativity, it was losing more than two hundred trillion tons of matter every second. Yet it could have gone on at this rate for over a year without losing as much as our earth weighs. In addition to this phenomenally bright nova, almost fifty other new stars have been discovered in the nebula, most of them being of the fifteenth or sixteenth magnitude. On the average, the Andromeda nebula seems to produce more than two novæ a year, a little more than our Milky Way system seems capable of. So frequent are these outbursts of novæ that they make us worry what their cause is. It does not seem reasonable to suppose that the past fifty years have been any different in the Andromeda nebula and in the Galaxy from the past fifty billion years, and we have every right to suppose that in that time at least fifty billion new stars have appeared on the scene. To this we must add that fifty billion years is but a short interval in the life of the average star and certainly small compared with the life of a universe. Our Milky Way system contains about fifty

SPIRAL NEBULA MESSIER 33 IN TRIANGULUM. EXPOSURE EIGHT HOURS, THIRTY MINUTES, AUGUST 5, 6, 7, 1910. SIXTY-INCH REFLECTOR

Photograph by Mount Wilson Observatory

CENTRAL PORTION OF THE GREAT NEBULA IN ANDROMEDA, MESSIER 31. EXPOSURE TWO HOURS, OCTOBER 13, 1909. SIXTY-INCH REFLECTOR

Photograph by Mount Wilson Observatory

SPIRAL NEBULA MESSIER 101 IN URSA MAJOR. EXPOSURE FOUR HOURS, FIFTEEN MINUTES, FEBRUARY 5, 1910. SIXTY-INCH REFLECTOR

Photograph by Mount Wilson Observatory

A UNIVERSE SEEN ON EDGE. SPIRAL NEBULA H.V. 24 IN COMA BERENICES EXPOSURE FIVE HOURS, MARCH 6 AND 7, 1910, SIXTY-INCH REFLECTOR.

Photograph by Mount Wilson Observatory

billion stars; we conclude therefore that during the past fifty billion years there have appeared as many novæ as our Galaxy contains ordinary stars. We are faced with the alternative, either that all stars have once been novæ or will become so in time, or, that "once a nova always a nova." Either the nova stage is one of the follies in the life of every ordinary star, or it is a disease, a habit, which, once contracted, recurs again and again.

The Andromeda nebula is not the only spiral that has new stars to its credit. These outbursts have been observed in about other eight spirals. Only very recently, in May, 1926, a new star of the fourteenth magnitude was discovered in the small spiral nebula Messier 61, in the constellation Virgo, —a fourteenth magnitude star,—in appearance an insignificant event, yet it was the echo of a powerful explosion which happened ten million years ago, transforming a perfectly normal-looking star into a veritable blast furnace, ten million times brighter than the sun.

Though the nearest of all spirals, the Andromeda nebula is not the nearest universe. Three others are known to be nearer, viz., the two Magellanic Clouds, situated at a distance of about 100,000 light-years, and a small star-cloud, (technically known as N. G. C. 6822) 700,000 light-years distant. These three are universes in vest-pocket edition, the size of the largest being no more than fourteen thousand light-years and that of the smallest only four thousand light-years.

It was from the Magellanic Clouds that the first clue to the distances of island universes came, for it was here that Miss Leavitt at Harvard first discovered that a relation exists between the apparent brightness of variable stars and the time it takes them to complete one cycle of their variation. Hertzsprung was the first to realize the extreme importance of this relation and to use it for determining distances in the cosmos. Later on, much use was made of it, in a modified form, by Shapley in his extension of the limits of the Galaxy from twenty thousand light-years to two hundred thousand. Now it has provided the basis for fixing the distance of the spiral nebulæ, extending our knowledge of space to tens and hundreds of millions of light-years.

In practically all respects the Magellanic Clouds are similar to our Galaxy; they contain star-clusters, nebulæ, variable stars of different types, blue stars, red stars, in short all the essential features of a universe. They are singularly lacking in one characteristic, however; they have never shown any new stars. Our Galaxy, the Andromeda nebula, and probably all spirals abound in them, but in spite of the close scrutiny with which the Magellanic Clouds have been watched, no new star has ever been observed in them. The same holds for N. G. C. 6822. Why this is so we do not know but, at any rate, this deficiency is not considered sufficient cause to cross the names of these three universes off our books, or even to put them on probation.

We do not know much about the constitution of these far-distant universes (outside the few mentioned specifically) but there is one thing which we know accurately about many of them, their speed in the line of sight. Observations with the spectroscope made principally at the Lowell and the Mt. Wilson observatories have shown us that the Andromeda nebula is approaching us with a speed of 200 miles a second, the Magellanic Clouds are receding from us at the rate of 170

miles a second. Most of the other spirals seem to be running away from us, all have great velocities, hundreds of miles per second. One spiral is even known to hurry away from us at the speed of 1100 miles a second. With reference to the whole system of spiral nebulæ, our Galaxy, and the sun with it, seems to be moving toward the constellation Cassiopeia, with a speed of 250 miles a second.

In addition to the spirals, we know thousands of small, amorphous-looking nebulæ, nebulæ which might be spirals so far distant that the most powerful telescope cannot reveal their structure. Yet it seems that these nebulæ, although obviously related to the family of spirals, are not identical with them; they are, perhaps, embryonic universes. The fact that so many of these amorphous nebulæ seem to crowd together in the sky, has given rise to speculations concerning possible collisions. Now collisions are things the astronomer does not worry about very often. In our Milky Way system a collision between two stars would not happen more than once in a trillion years on the average. But among these nebula the case is different. Charlier has calculated that nebulæ may collide once in a thousand years. And what is a thousand years in the life of a universe? When two such amorphous nebulæ meet or come very near each other, it is quite possible that a spiral nebula will result. At present we possess photographs of many cases where, in a few million years a spiral nebula may be generated. We have never witnessed the birth of a universe, nor are we likely to. The process involved is too slow and does not at all compare as a spectacle with that of the birth of a new star. All that happens is that two swarms of stars meet, and gravitate around their common center of gravity. Indeed, there are indications that the Galactic system is at this moment in "collision" with another universe, manifesting itself as a swarm of stars penetrating the Milky Way at high speed.

What, then, is the present-day picture of the cosmos? To begin with what, is a star? A sphere of glowing gas, varying in size from a globe not much larger than the earth, to one a thousand times larger than the sun in diameter, large enough to take in the entire orbit of Jupiter. In density it may vary from a thousand times rarer than our atmosphere, to fifty thousand times denser than water. Next comes, what is a universe? One answer would be: a vacuum. Take our Milky Way system, e. g., although it contains more than 50 billion stars, the space over which these are scattered is so enormous that we may compare the whole Galaxy to a cubic foot of normal air, spread out over ten cubic miles!

In size, the lens-shaped core of the Milky Way system is about fifty thousand light-years in diameter and no more than ten thousand light-years thick. Outside this nucleus there lie the globular clusters, at distances up to 200,000 light-years, and perhaps some of the more distant Milky Way star-clouds. The first strangers we meet beyond are small islands, the Magellanic Clouds, and N. G. C. 6822, then, at one million light-years, the spirals in Andromeda and Triangulum, not more than fifty thousand light-years in size. So far we have struck only real "Island" universes; a continent as large as our own we have yet to find. But who knows what Space beyond contains? Universe upon universe, some small, some large, and undoubtedly some very large.

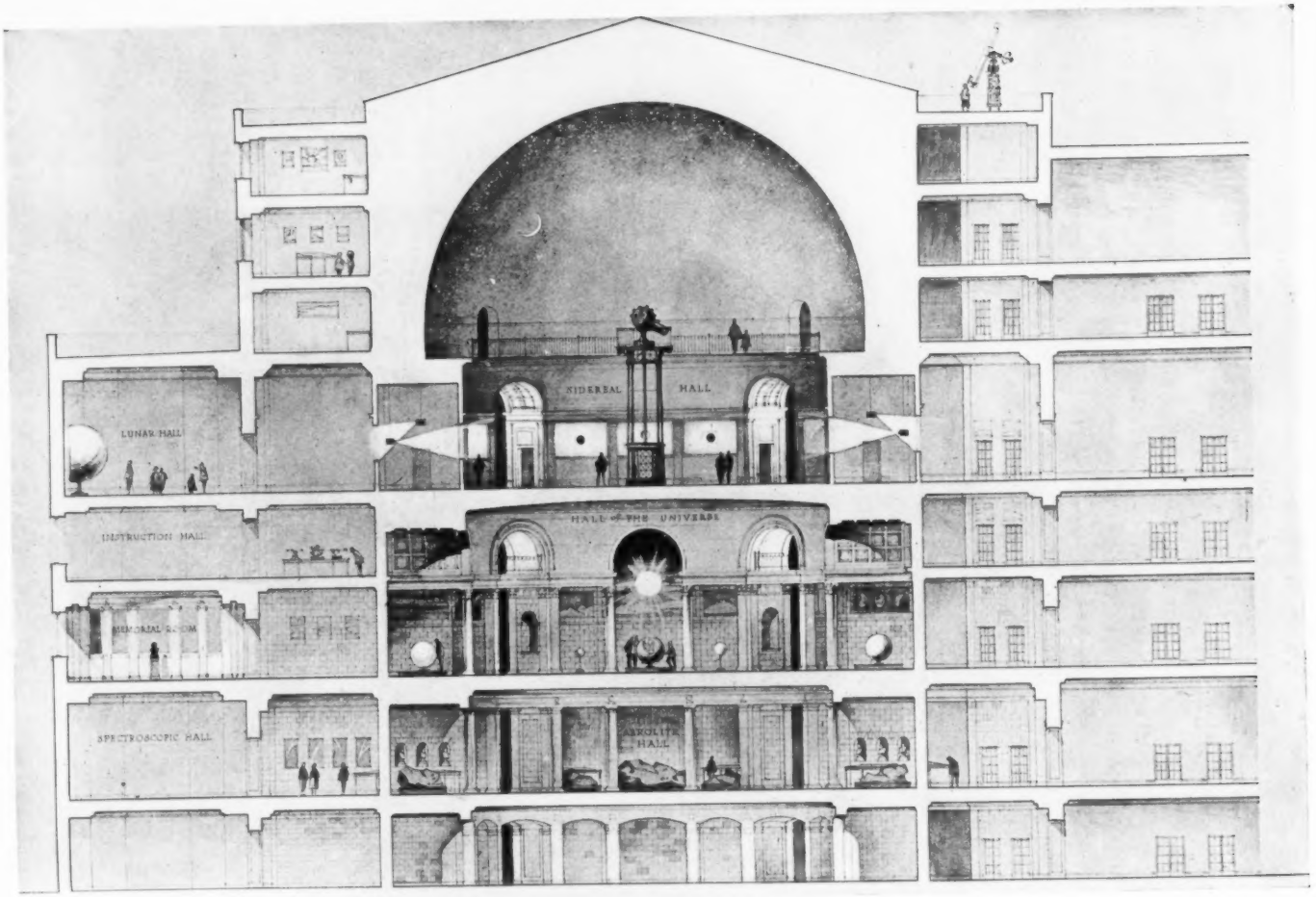
Following the tendency of all science

toward "unity and simplicity," astronomical opinion has repeatedly considered everything as part of "our" universe. Equally frequently, however, the dual tendency toward "diversity and complexity" has led us to views like those held now, supposing the existence of numberless universes. Perhaps the future will see us again returning to the Single Universe. Again, everything material will be contained in one system, of much increased dimensions, of course, billions of light-years in size perhaps.

But no matter how far we may go, we shall never reach the end, neither in space nor in time. No matter how far we proceed in space or in time we never advance against infinity and eternity. The ubiquitous myriads of scintillating flashes confront us everywhere, they stagger the mind and overwhelm the intellect—an *infinitas in aeternitate*. And yet, as Pascal, we may feel satisfied with our accomplishments:

> We are little, almost the least and weakest of things; but we know that we are little and therein we are great.

NIKOLAUS COPERNICUS
From the original in the Royal Observatory at Berlin.
After *Weltall und Menschheit*



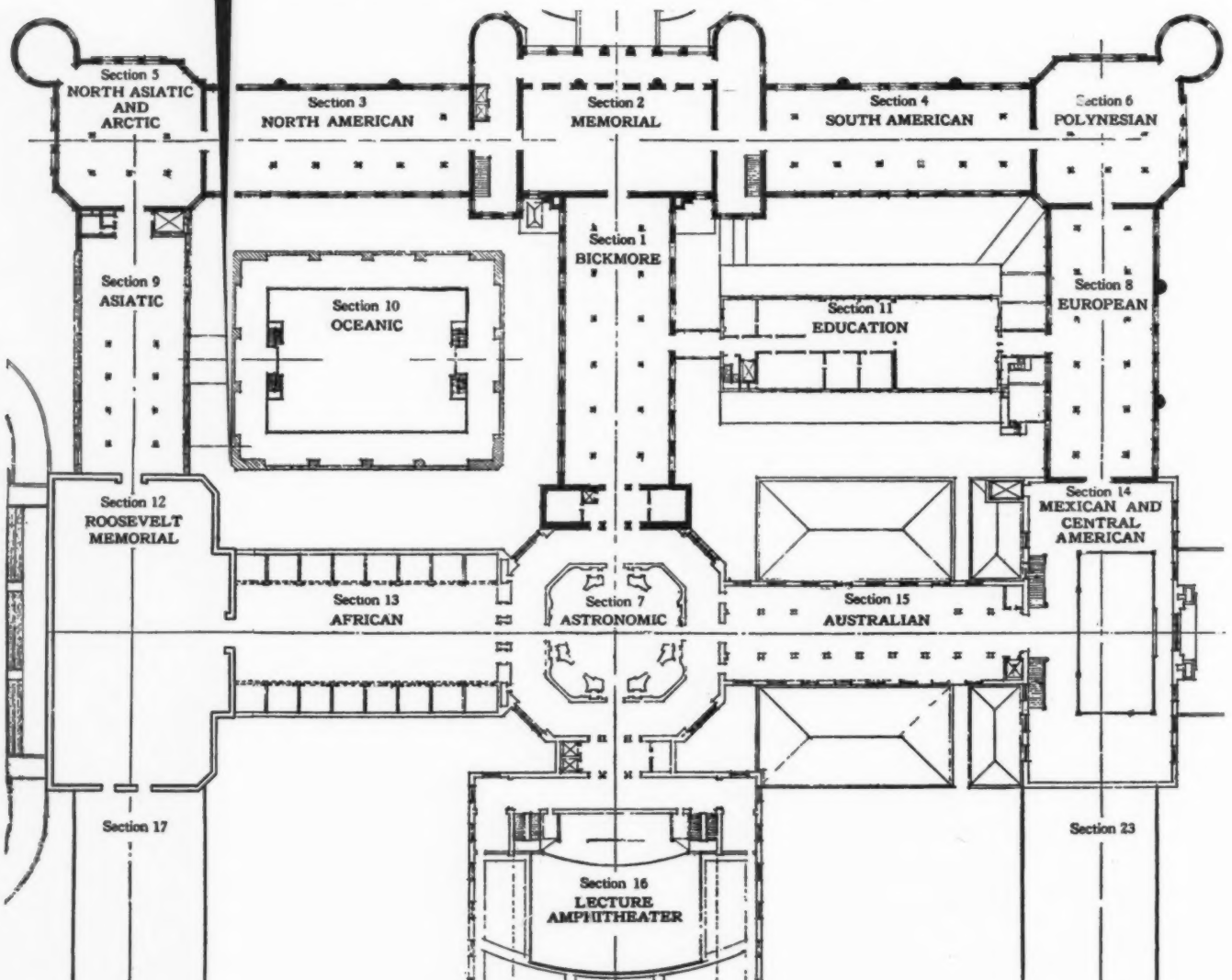
PROPOSED ASTRONOMIC HALL

Longitudinal section, looking southwest

PROPOSED ASTRONOMIC HALL
Longitudinal section, looking southwest

UNIV. OF MICH.

GENERAL BUILDING PLAN OF THE AMERICAN MUSEUM OF NATURAL HISTORY



An Ideal Astronomic Hall

By HOWARD RUSSELL BUTLER

THE proposal of the American Museum of Natural History to construct a hall to be devoted to astronomical and kindred subjects has been conceived at the right time, for it can now be made far more serviceable than would have been possible had it been erected a few years ago. Advance in the line of astronomical exhibits has been rapid lately. Take for instance the Zeiss Planetarium. This marvelous instrument projects on the inner surface of a dome about 4,500 fixed stars, and even the Milky Way is shown as a starry mist. It reproduces the diurnal and annual motions at any desired speed. It also pictures the sun, the moon, and planets, giving their motions within an error, it is claimed, of less than one per cent. It can show the precession of the equinoxes, not in 26,000 years, but in twenty-six minutes. The enormous educational value of this instrument, which solves the problem by optical means rather than by mechanical, and which has awakened such phenomenal interest in Germany, makes it an absolutely necessary adjunct to an astronomic hall—if not its chief attraction. Had the Museum built its hall ten years ago, provision for this unique device would not have been made, and instead, cumbrous mechanical contrivances for showing the movements of a few of the heavenly bodies would have been attempted, necessarily on a limited scale. So I congratulate the Museum on not having been too hasty.

Again I would congratulate the Museum on the wise decision to locate the Astronomic Hall in the exact center of its great system of exhibition buildings. It is indeed appropriate that this should be the central unit,—the celestial hub, so to speak,—from which all the halls containing terrestrial exhibits will radiate. Natural history must begin with astronomy, the earth being but one of the heavenly bodies, and a somewhat insignificant one at that.

The plans, as recently completed, show a building octagonally shaped, with a diameter of 126 feet and a height of five stories, surmounted by a dome. The ground dimensions having been fixed, the Trustees and their architects, Messrs. Trowbridge and Livingston, evolved a general plan along broad and practical lines. Interior divisions were not finally determined, as these would be dependent upon the uses to which the building would be put.

At this stage, I was invited to the position of adviser to the architects.

Before the plan could be perfected in detail, it was necessary to catalogue so far as possible the long list of exhibits to be housed in the building, and my first effort was to canvass the field. A complete list is of course impossible, and the future will also bring many important additions for which space must now be allowed. A wise principle adopted by the Museum is to admit no exhibits except those approved for accuracy by experts. Sensational effects and shallow exaggerations, not based on facts, would do more harm than good. Nature, unassisted, affords enough thrills.

In making the list, the adviser had the assistance of the late Dr. John Tatlock, president of the New York

Academy of Sciences; Dr. Henry Norris Russell, who made many valuable suggestions; Professor William F. Magie, in regard to the Foucault Pendulum; Dr. Clyde Fisher, of the Museum; and Messrs. Bennett & Bauer, of the Zeiss Company, on the subject of the planetarium.

The next problem was that of classification, and after that came the problem of adaptation of the spaces in the building to such classification. This was really the determining factor in the final plans for construction. The arrangement of floor spaces, (rotundas, alcoves, camera booths, and ambulatories) as well as the size of the dome, have been made to suit the classified exhibits.

The final plan calls for a dome 75 feet in diameter, supported at its circumference by a series of steel columns penetrating the building from the ground to the base of the dome. These leave a space for circumferential ambulatories about 20 feet wide, one on every floor between the columns and the outside walls. Another and inner series of columns strengthens the whole structure, leaving spaces for central rotundas on the first, second, and fourth floors,—all 62 feet in diameter.

The exhibits naturally fall into two classes: those which have to be shown in dark rooms by special illumination, like lantern projections, transparencies, underlit pictures, etc.; and those requiring ordinary diffused light (daylight or full electric light) such as globes, photographs on paper, charts, instruments, etc.

A building of this shape and in this position, surrounded by others, is necessarily cut off to a great degree from daylight. Little daylight can reach the central rotunda, and the same is true of much of the ambulatory space. It is therefore fortunate that its mission is one which calls especially for artificial light.

DARK SECTION

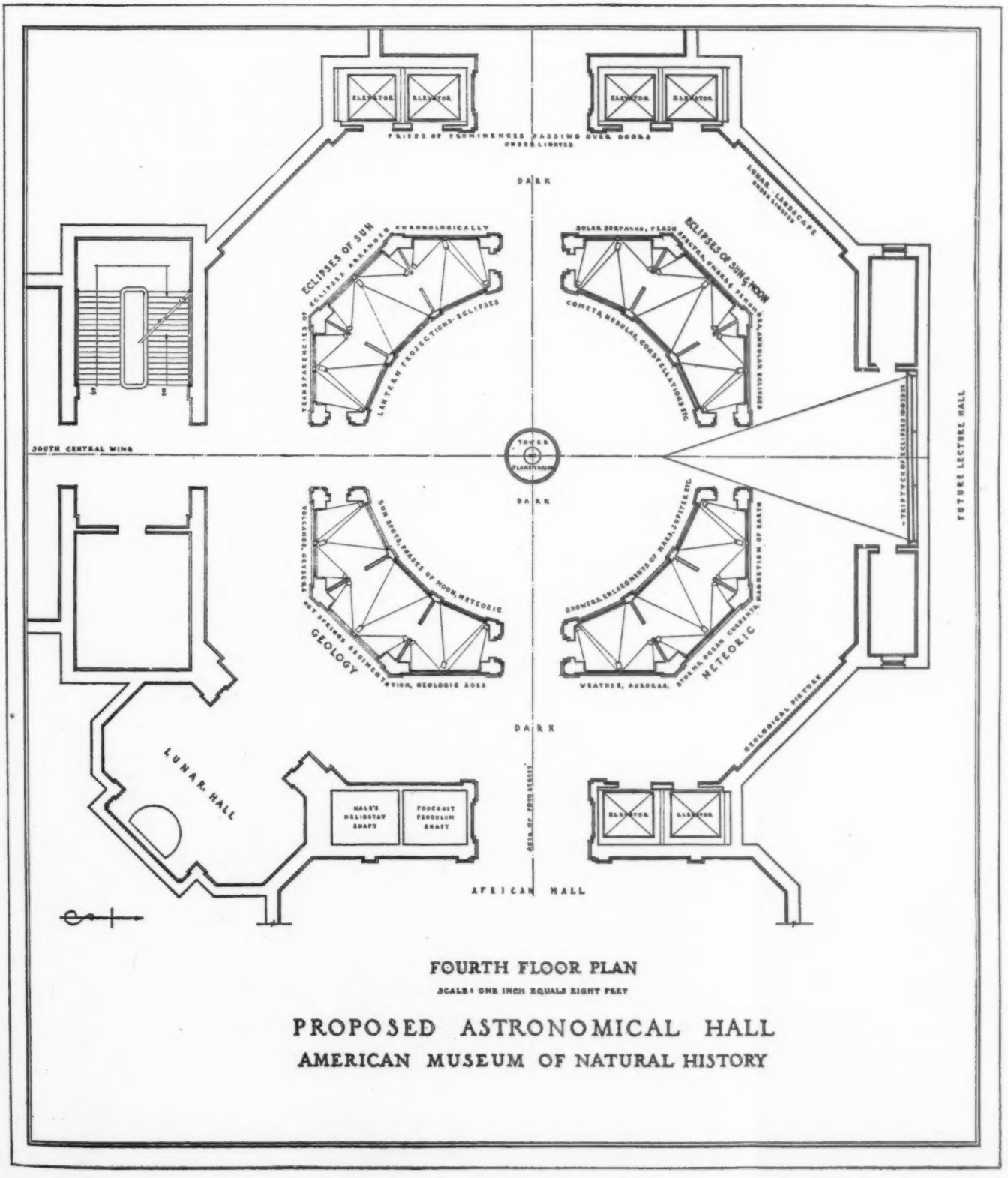
SIDEREAL HALL

An early decision was reached in conference to keep the fourth floor (with its dome, rotunda, and ambulatory) dark, and to have diffused light (windows supplemented by electric light) on all the lower floors.

Beginning at the top, as visitors should, and working down, the exhibits of the dark section fall into four classes.

I. Siderial projections on the inner surface of the dome. For these the Zeiss planetarium will be used, a tower being provided to bring it to the proper altitude. The inner surface of the dome is white and the effect of stars is obtained by means of a powerful lantern which throws slides made from drawings based on photographs of the heavens. There are thirty-one of these diapositives, which fitting together, give the complete heavens. Special projections are used for the Milky Way and others for the sun, moon, and visible planets. A gallery on the level of the fifth floor, bringing the eye of the observer to the horizon, encircles the room considerably above the main floor of the rotunda, which is the fourth story of the building. This separates those interested particularly in the projections on the dome from the visitors on the main floor of the rotunda. An alternative to this plan would be to make the fourth floor rotunda only one story high, to abolish the tower and place the lantern of the planetarium in the center of the floor of the fifth story.

II. Twelve panels, carrying trans-

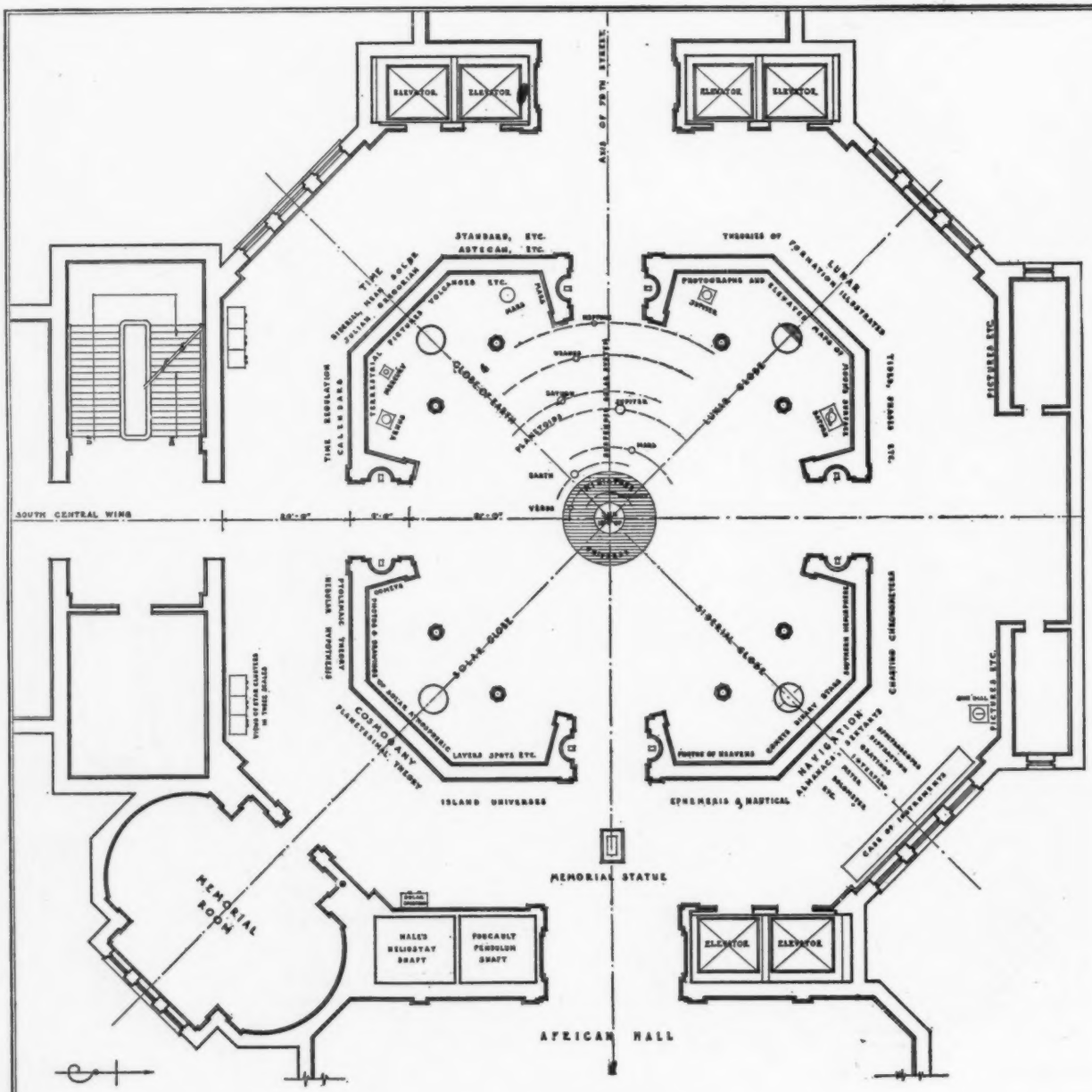


FOURTH FLOOR PLAN

SCALE: ONE INCH EQUALS EIGHT FEET

PROPOSED ASTRONOMICAL HALL

AMERICAN MUSEUM OF NATURAL HISTORY



SECOND FLOOR PLAN

SCALE: ONE INCH EQUALS EIGHT FEET

PROPOSED ASTRONOMICAL HALL

AMERICAN MUSEUM OF NATURAL HISTORY

View in proposed Astronomic Hall showing dome of projection planetarium

luscent screens are arranged around the rotunda. Lanterns, placed behind these screens, in the spaces between the two series of columns, throw projections on the screens of astronomic slides of great variety. These can be shown automatically and rotatively. It was a matter of nice calculation to determine the size of these pictures and the spaces required for the lanterns between the series of columns. An experimental camera booth was erected, and demonstrations made by representatives of the firm of Bausch & Lomb. A wide-angle projector was determined upon and the delimitations of con-

VIEW IN THE HALL OF THE UNIVERSE, SECOND FLOOR
PROPOSED ASTRONOMIC HALL

struction were thus accurately fixed.

III. The inner face of the ambulatory, which surrounds the rotunda and is approached through four openings, is devoted entirely to transparencies, which fall into four divisions, as follows:

(a) Solar eclipses, arranged chronologically.
(b) Solar and lunar eclipse phenomena.
(c) Meteoric division.
(d) Geologic division.

IV. The outer face of the fourth floor ambulatory is devoted to underlit pictures, such as the triptych of eclipses (1918, 1923, 1925) recently placed on view in the temporary astronomic hall of the Museum of Natural History; lunar landscapes; eclipse photographs; a frieze of hydrogen prominences; and such geologic pictures as have astronomic bearing.

A wing on one of the faces of the building provides a space availed of on this floor as a "Lunar Hall," accommodating a lunar globe, ten feet in diameter, with a system of lighting to show phases.

VIEW IN THE HALL OF THE UNIVERSE, SECOND FLOOR
PROPOSED ASTRONOMIC HALL.

LIGHT SECTION
HALL OF THE UNIVERSE
Second or Main Floor

Everything below the fourth floor is shown by diffused light. A rotunda, two stories high, occupies the space between the second and the fourth floor. Here in the center will be a miniature universe—a number of fixed stars being selected, represented by electric lamps, showing relative distances apart and color, but without any attempt to show relative dimensions. The position of our sun in this group will be a point of great interest. Above this, about fifteen feet above the floor, is a miniature solar system suspended in mid air, somewhat similar to that in the Munich Museum. The illuminated globe in the center represents the sun. The six planets nearest the sun, with satellites, (the planets and satellites all revolving at their proper relative speeds), are shown. The orbits of Uranus and Neptune are left out in order not to diminish the scale too much. The diameter given to the orbit of Saturn would be about 60 feet.

Surrounding the rotunda are four alcoves divided by columns, making three openings in each. In the central openings are large globes;

(1) Sidereal globe.
(2) Solar globe.
(3) Terrestrial globe.
(4) Lunar globe.

Smaller planetary globes are placed in the other openings, and the interior walls of the alcoves are hung with pictures appropriate to the globes.

The inner face of the ambulatory is also divided into four corresponding sections.

(1) Navigation (sidereal globe section).
(2) Cosmogony (solar globe section).
(3) Time and calendars (terrestrial globe section).
(4) Lunar, tides, etc. (lunar globe section).

Around the outer walls of the second floor ambulatory are cases of instruments, above which are hung photographs of astronomical subjects, portraits of astronomers, etc.

Thus the student of navigation will find everything pertaining to that subject in one division—maps, charts, and log tables on the wall and in near by cases, sextants, chronometers, nautical almanacs, etc. The student of cosmogony finds a section giving him

information about the Ptolemaic and Copernican theories, the nebular hypothesis, the planetesimal theory and the "island universes." In the "Time Section" the investigator learns about the various calendars, the differences between sidereal, mean solar and standard times, the principles of the sun-dial with examples of the various types near at hand. An investigator of power sources could find out all about tides in the "Lunar Section." The educational value of these sections cannot be overestimated.

A Memorial Hall is provided on this floor designed to commemorate the donor or donors of Astronomic Hall. It would open from the ambulatory of the main floor, while, if the funds should be given by a single individual, a statue of the donor could be placed at the main entrance to the hall as shown in the plans, — this in line with the central entrance to the Museum on Eighth Avenue.

The third story consists of an ambulatory and balconies, giving upon the "Hall of the Universe." This is reserved for qualified students only. Lectures and demonstrations would be given here, and here would be kept all the instruments used in instruction and the many forms of planetaria, such as are seen in the German museums. A hall in the wing is provided for the lectures and for astronomical moving pictures. From the balconies of this hall the student will have an excellent view of the miniature solar system.

AËROLITE HALL

First Floor, Street Level

The arrangement of alcoves here would be somewhat similar to that on the second floor. The aërolites are arranged symmetrically in alcoves, the great aërolites in the largest openings. This arrangement brings the piers necessary to support their weight into positions outside the central hall of the basement, combining these piers with the foundation footings of the steel columns.

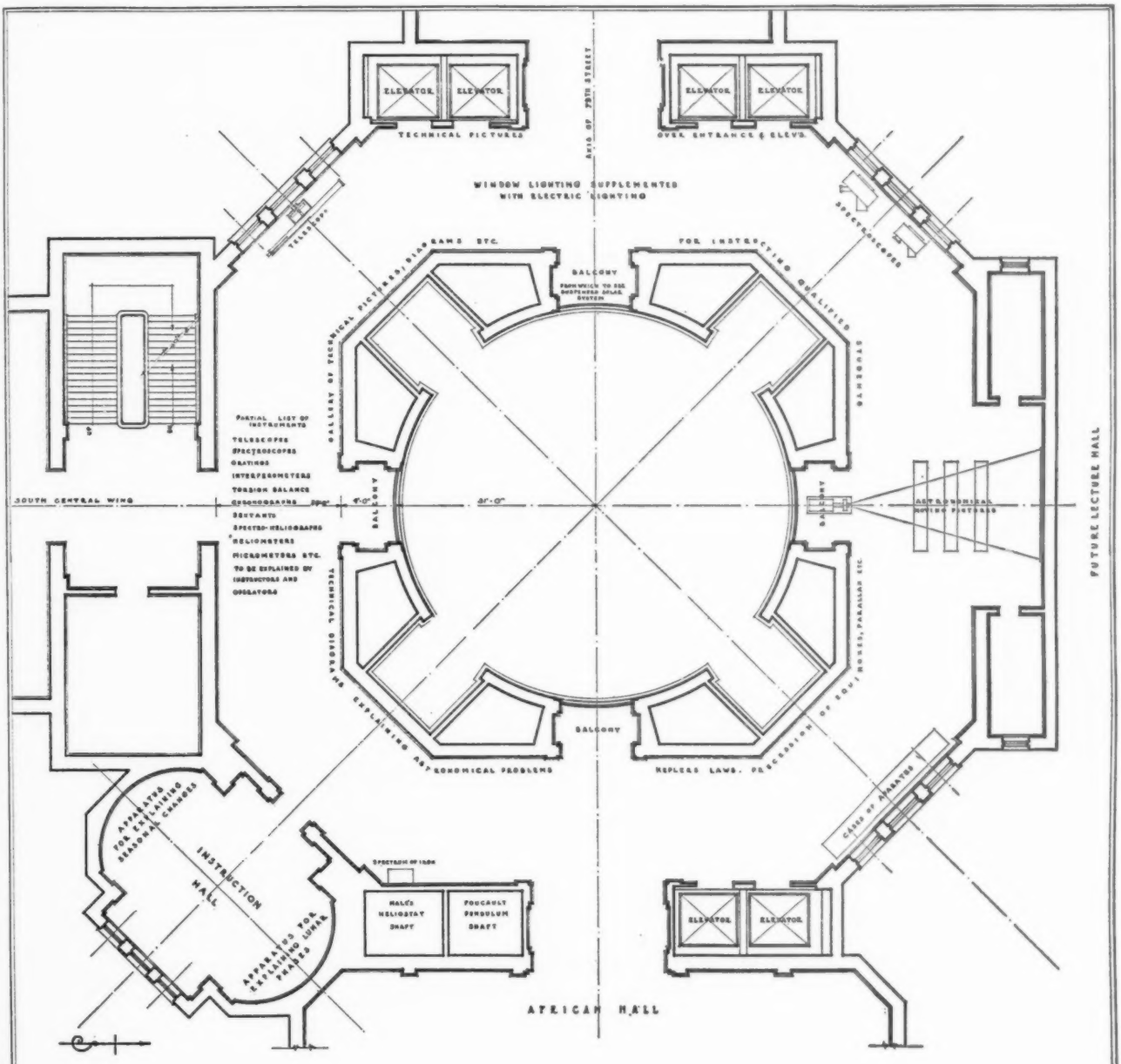
SPECTROSCOPIC HALL

First Floor, Continued

This is under Memorial Hall and is entered from the ambulatory of the first floor. It adjoins the shaft of the Hale Heliostat and here beams of sunlight brought down the shaft can be utilized for spectroscopic projections.

Vertical shafts are provided for the Hale Heliostat and the Foucault Pendulum, terminating on the first floor 120 feet below the roof platform. Adequate elevator service is provided, even to the observation platform on the roof, where a telescope and transit will give opportunity for observation of the heavens themselves.

The time has certainly come for the erection of a great educational hall of the type designed. It is not right that the United States should longer remain behind other nations in a field so important and so absorbingly interesting. The American Museum of Natural History is, beyond question, the organization best qualified to undertake the project. It has an unsurpassable site, situated at the heart of the largest city of the Union. May the means soon be forthcoming and may the opening of the doors of its proposed Astronomic Hall soon be realized.

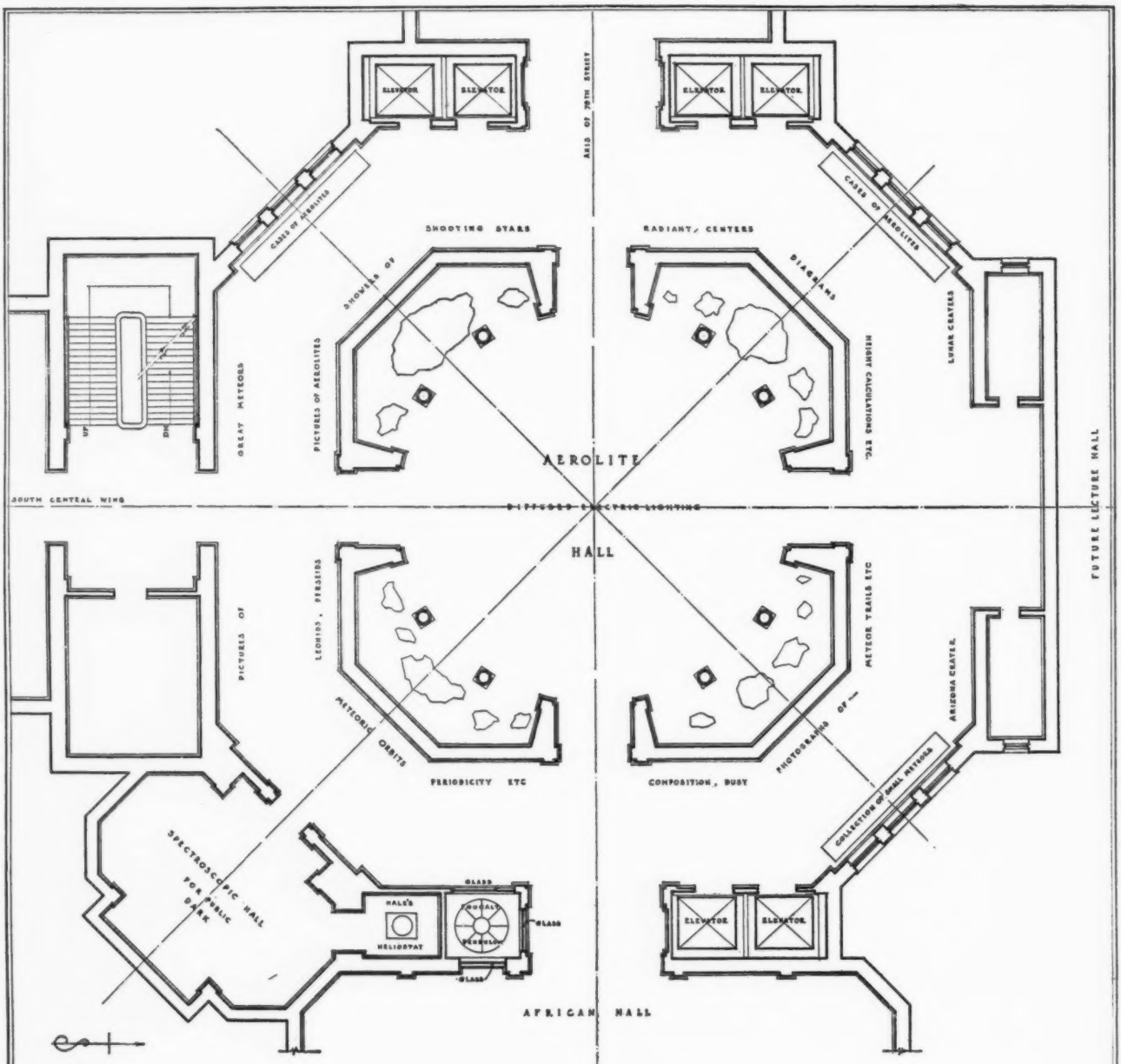


THIRD FLOOR PLAN

SCALE: ONE INCH EQUALS EIGHT FEET

PROPOSED ASTRONOMICAL HALL

AMERICAN MUSEUM OF NATURAL HISTORY



FIRST FLOOR PLAN

SCALE: ONE INCH EQUALS EIGHT FEET

PROPOSED ASTRONOMICAL HALL

AMERICAN MUSEUM OF NATURAL HISTORY

The Use of Models in an Astronomical Museum

By HENRY NORRIS RUSSELL, Ph.D.
Professor of Astronomy, Princeton University; Director of Halstead Observatory

THE words "astronomical museum" might suggest to many astronomers a collection of ancient apparatus which had been relegated to such an environment after they were no longer of practical use in the observatory, but there is no reason whatever why these words should have such a connotation. While a museum cannot be so intimately connected with the work of research in astronomy as it may be in geology, or ethnology, it may perform a distinctive service in connection with its other great function, that of education, both of the general public and of more specialized students of the science.

Direct telescopic observation, which of course has a unique value, is rarely practicable for the public, and suffers under limitations of time even for university students. These difficulties may be considerably obviated by the use of photographs, in a manner very familiar. But it is not generally recognized that suitably prepared models may perform a mission quite distinct from that of even the best photographs.

This principle has long been recognized in the field of natural history, using the word in its narrower sense. The habitat groups which adorn the greater museums convey a wealth of constructive information, even to the casual onlooker, with which no photograph, however excellent, could possibly compete. Is it not practicable to do the same in the case of the heavens?

The more obvious instances, such as the preparation of globes representing the moon and perhaps Mars or Jupiter, have already been frequently attempted. A more ambitious and very successful attempt is found in the modern planetarium. But many other possibilities appear to be open, and it may be worth while to speak briefly of a few, and especially of working models which exhibit characteristics which photographs cannot do.

The chief difficulty in explaining many astronomical problems to the non-mathematical listener is found in the fact that the relations which are concerned are essentially three-dimensional. The power to form a clear mental image of the relations of several bodies in space is somewhat unusual, and pictures in the flat, even the best perspective drawings, do not altogether solve the difficulty; while a model in which the relations are actually represented in three dimensions will often make things clearer.

Consider, for example, solar and lunar eclipses. By a suitable model in a nearly darkened room, in which all the light came from a circular opal glass disk or globe, near one wall, the umbra and penumbra of the shadows of the earth and the moon, the track of the moon's shadow across the rotating earth, and the phenomena of total, partial, and annular eclipses, could all be exhibited. It would be impracticable to construct such a model exactly to scale, but the principles involved could be very clearly illustrated and the mechanical complications need not be at all prohibitive.

Again, in the planetary system, many of the characteristics of planetary motion could probably be best exhibited with the aid of moving pic-

tures. Were it practicable to prepare a film after the manner of the "animated cartoons," which are commercial commonplaces, it would be possible to show the motion of a planet or comet in an elliptic orbit with velocity varying in accordance with Kepler's laws. Such a film, showing for example the motion of Halley's comet, with some indication of the change in brightness and the growth of the tail at perihelion, would be exceedingly instructive. Similar diagrams could be used in the case of binary stars to exhibit both their orbital motion around the center of gravity and the rectilinear motion of this point across the heavens.

But it is among the stars that the potentialities of the astronomical models are perhaps the greatest. Though they seem to us but dimensionless points of light, our knowledge of the stars is now sufficient to justify the construction of scale models showing their relative positions in space and others exhibiting their true dimensions. The incandescent light here furnishes us with the great advantage that the stars can be represented as luminous points, whose differences both in brightness and in color can be adjusted so that they resemble closely those which actually exist among the stars. A series of lamps, hung by almost invisible wires, could thus form a model representing the position of the sun and the nearer stars in space, and such a model would have the great advantage that corrections or additions could readily be made to it as the discovery of those stars which are our neighbors in space progresses.

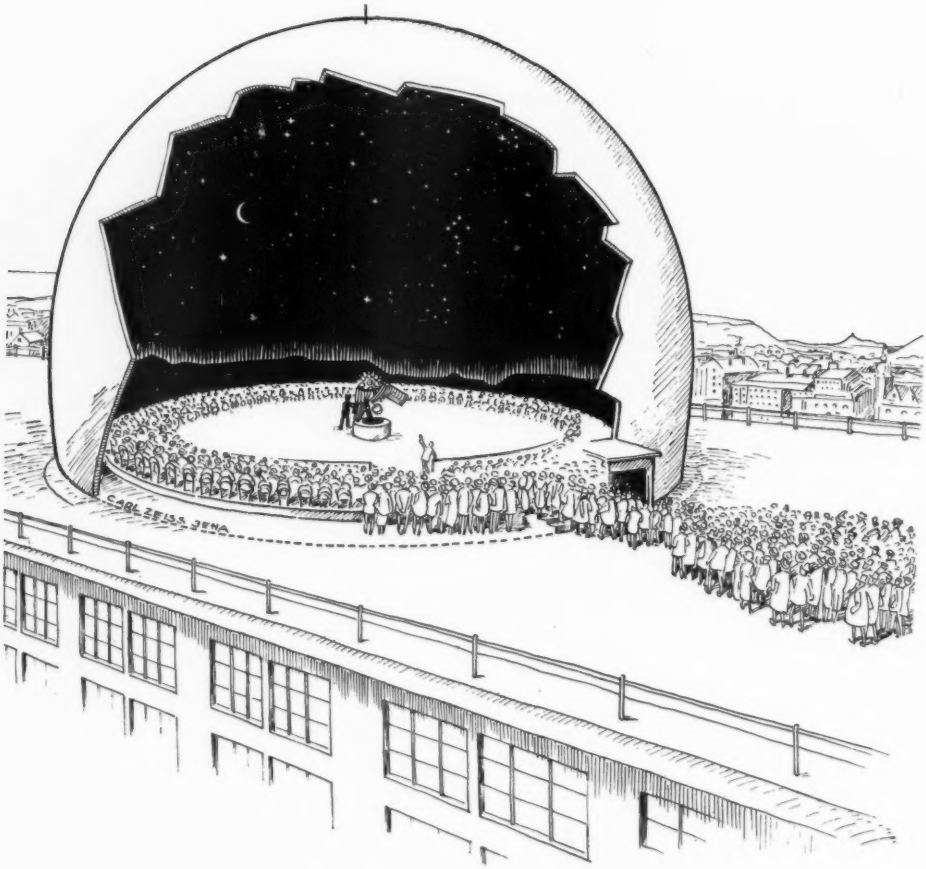
It would be entirely possible, also, to prepare models in the form of translucent globes, illuminated by lamps within, which illustrated both the relative size and the relative brightness of such bodies as the sun, Sirius, Arcturus, Rigel, and Betelgeuse. Most interesting of all would perhaps be models of eclipsing variable stars. In this case two such globes of different size and brightness would be set up at a proper distance and caused to rotate about a common center so that each eclipsed the other at regular intervals. There are numerous systems in which the true dimensions are accurately known, and with such a model the visitor might follow for himself the progress of the changes which, as they occur in the heavens, would be exhibited by a photograph annexed to the model.

Still another possibility which occurs to the writer, is that of a graphical representation of the relative magnitudes of astronomical distances, by means of a series of models, maps or diagrams, each on a scale one hundred times smaller than the last. For example, one might begin with a photograph of the room in which the exhibit is placed on 1/100 or 10^{-2} of its actual scale. The next stage might be an aërial photograph of New York City, showing the Museum and its environs, on a scale of 1/10,000 or 10^{-4}. The next, on the scale of 1/1,000,000 or 10^{-6}, could be represented by a sheet of the international map of the world. On this scale the earth is about twenty feet in diameter, as is illustrated by segments of a globe, showing the polar regions, which are now in the Museum. In the fourth stage, scale 10^{-8}, the earth would be about 5 inches in diameter, the moon rather more than an inch, and about thirteen feet from the earth. In the fifth stage the earth and moon would be about one and one-half inches apart and the sun fifty feet away and not quite six inches in diameter. The sixth stage would re-

duce the sun to about 1/16 of an inch, and put the earth six inches from the sun. The smaller orbits of the planetary system could be well mapped on this scale. The seventh stage would show Neptune's orbit not quite four inches in diameter, and could exhibit some of the larger cometary orbits which are well determined. On the eighth stage Neptune's orbit would have shrunk almost to a dot, some of the cometary orbits would still be visible and the nearest fixed star would be some forty feet from the sun. The ninth stage would bring the nearest star within a few inches of the sun and would be well adapted for a model showing the distribution of the stars in space. Two more stages would be required before a model of the Andromeda nebula could be shrunk to practicable dimensions.

The same scheme reversed, so that objects were magnified instead of diminished, might perhaps be used to exhibit the modern discoveries concerning atomic structure. Magnifications of one hundred- or ten thousandfold can be reached with a microscope. The third stage might be used to illustrate the ultra-microscopic particles which occur in colloidal solutions. The fourth would exhibit the arrangement of atoms in crystals, the fifth the structure of the inner electron orbits in the heavier atoms; while on the sixth the electron itself would begin to become a visible speck.

Such a series of models, if its preparation should prove practicable, would, in all probability, lead to a realization of the relative magnitudes of the various bodies with which modern science deals, and would be much more vivid than anything that can readily be obtained at present. The writer will confess frankly that the realization of this series is one of his dreams because he would like very much to see it himself.



Sectional view of the Zeiss Planetarium

The New Projection Planetarium

By CLYDE FISHER
In charge of Astronomy, American Museum of Natural History

And that inverted Bowl they call the Sky—The Rubaiyat

SOMETHING new has appeared in the realm of science, something fundamentally different from all achievements of the past years in this particular field. It is an instrument grand in conception and fully realized in its development, an instrument for the purpose of popularizing the great subject of astronomy.

Our prehistoric ancestors were greatly interested in the planets and the stars and in the sun and moon, and made considerable strides in comprehending their movements. The misunderstandings of students before the time of Copernicus and of nearly all persons for more than a century after, were quite natural, for the earth certainly seems to be in the center of the universe, and all the heavenly bodies seem to revolve around the earth. As is well known, the idea that the earth rotates on its axis and that the sun is the center of motion of the earth and other planets was not accepted without great opposition. The vicissitudes of this theory, known as the Corpernican system, the burning of Bruno at the stake, and the punish-

ment of Galileo are common knowledge.

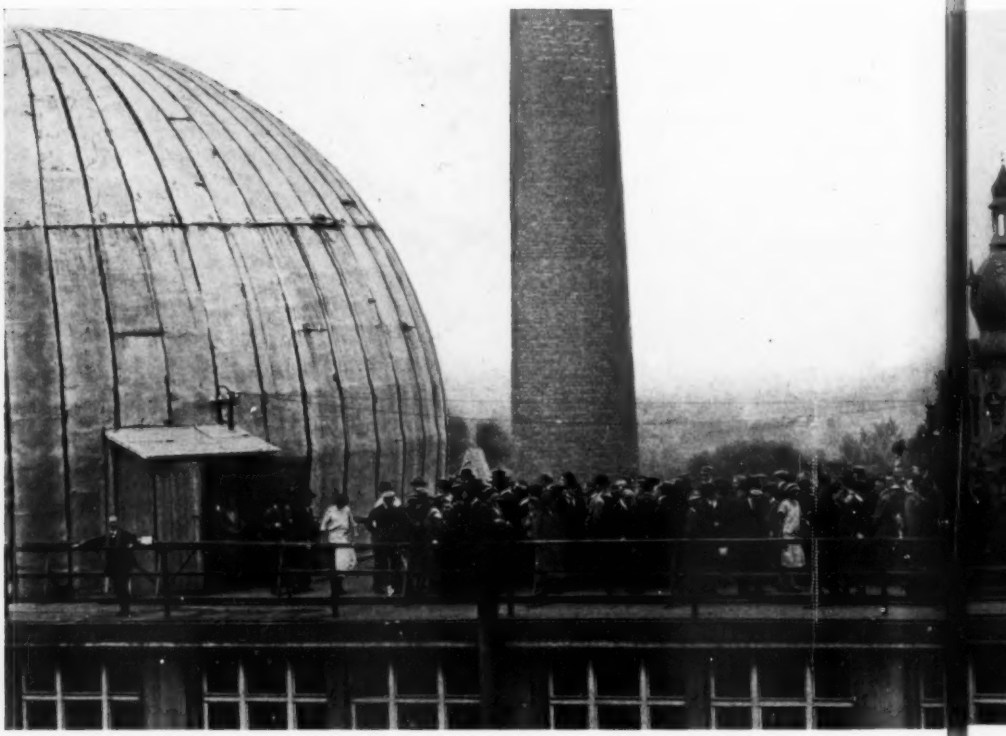
It is true that mechanisms known as planetariums showing the relative motions of the sun, moon, and planets are not new, but have been constructed at various times since the days of Huygens (1629–95) and Roemer (1644–1710). In England a complicated machine of this type was built for Charles Boyle, the fourth Earl of Orrery (1676–1731), which was named for him, thus originating the word "orrery," now frequently applied to such pieces of apparatus. These machines consisted of a series of globes to represent the various bodies of our solar system, each revolving globe supported by a metal rod, the whole system of sun and planets and satellites being connected and propelled by gears so that their relative motions were approximated. The earlier ones had much to do with the final general acceptance of the Copernican system and, ever since their first appearance, these devices have had and still have great value in teaching, the three-dimensional mechanisms capable of simulating the motions of the heavenly bodies being incomparably more effective than flat pictures or pages of printed text.

Some of these mechanical planetariums or orreries have been made with great ingenuity and skillful workmanship. The best ever constructed was made by the Carl Zeiss Optical Works and is installed in the German Museum in Munich. It may be briefly described as follows: A lighted globe in the center represents the sun. The six planets nearest the sun, with their satellites—the planets and satellites all revolving at their proper relative speeds—are shown. The diameter of Saturn's orbit is about forty feet. Uranus and Neptune are left out, I presume because their tremendous distances would make the rest so small proportionately. There is no light except from the central sun, and the walls, ceiling, and floor are painted black. Consequently, day and night are well shown on any of the six planets, and so are the phases of our moon. For the lecturer or demonstrator, a car travels around under the earth, which goes around the sun in twelve minutes, the apparatus being propelled by an electric motor. The phases of Venus and Mercury can easily be observed. The constellations of the zodiac are shown in a belt on the wall, with their names in white letters and with the degrees of the circle marked. The principal stars are shown by lights back of small, round holes in the black wall.

Yet, in view of all this, it is quite plain that these old-fashioned planetariums or orreries were very crude

This way to the Projection Planetarium, at the Zeiss Optical Works, Jena

and unsatisfactory at best. All were built on a small scale and the observer had to watch the various movements of the heavenly bodies from the *outside* of the solar system, and not as one

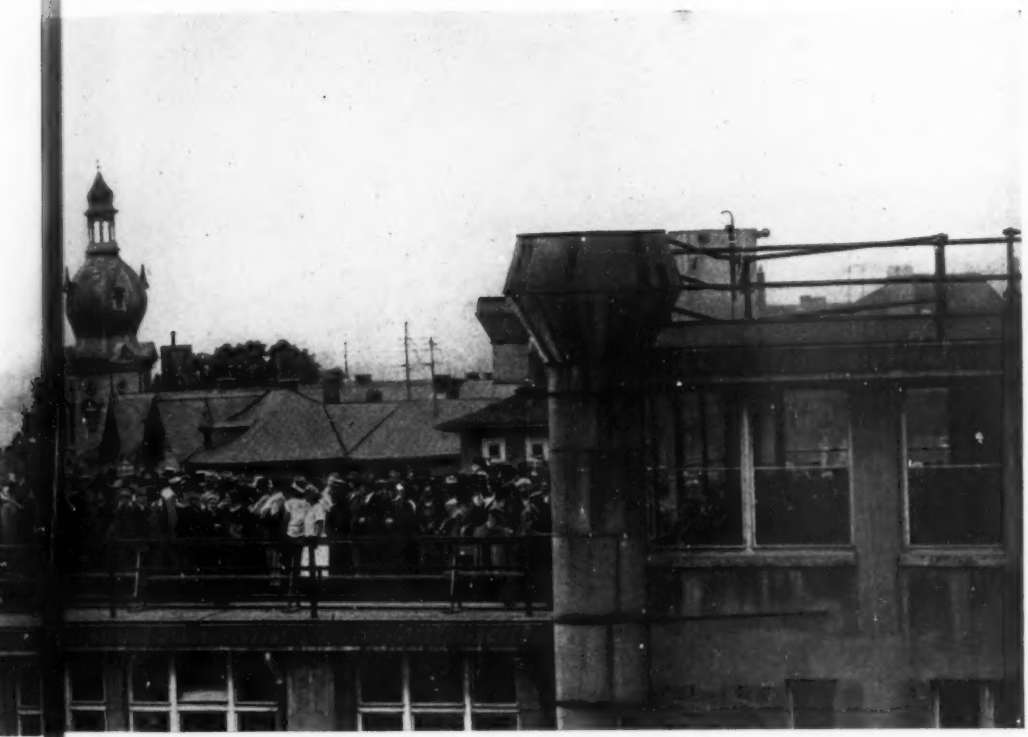


Zeiss Projection Planetarium on the roof of the Carl Zeiss Optical Works,

observing from the earth. And in all cases the comparative sizes and distances were more or less extremely distorted. And again, the fixed stars, which so enthrall us in the night sky, were always left out, although sometimes shown in an inadequate manner by being painted on the surface of an outside sphere or zodiacal zone or belt. It is true that some of these defects were partially overcome in the large Copernican planetarium in Munich, described above, but all of the old type are conspicuously inadequate in comparison with the new projection planetarium.

One of our American astronomers, in a recent number of a magazine devoted to astronomy, says "it has been reserved for Dr. Bauersfeld of the Carl Zeiss Optical Works in Jena to make the first complete solution of this problem, so significant in the ultimate popularizing of the noblest of the sciences, thus enabling for the first time in history the 'man on the street' to comprehend quite as fully as the learned professor, the seemingly intricate, though actually simple workings of the celestial mechanism."

Before the outbreak of the World War, Dr. Oskar von Miller, director of the German National Museum at Munich, approached the Zeiss firm regarding the construction of a planetarium which would show the movement of the heavenly bodies according to the Ptolemaic system on the interior of a hemispherical dome in the same manner as they appear in the heavens to an observer on the earth, that is, to one *inside* the universe. The first idea considered was to represent the stars by small electric bulbs attached to the dome which would have to be rotated around an axis parallel to the earth's



Works, Jena, Germany. Crowds arriving to witness a demonstration

axis. The sun, moon, and planets were to be represented by illuminated discs driven by suitable gearing in such a way that the epicycle orbits of the heavenly bodies would be truly represented. It soon became evident, says Dr. Ing. W. Bauersfeld, that it was impossible to solve the problem in this manner, and the outbreak of the war put a stop to the work. It was taken up again after its close, but the problem was attacked from an entirely different point of view.

The basic idea of the solution was to have the hemispherical dome fixed and to throw images of the heavenly bodies on the dome by means of a projection apparatus located at the center of the dome, the apparent movements of the sun, moon, planets, and stars to be accomplished by the mechanism of the projection apparatus.

In 1924 the first projection planetarium was completed and installed in the Munich Museum. In September, 1925, it was my good fortune to be sent to Germany by the President and Board of Trustees of the American Museum of Natural History, for the purpose of examining this apparatus with a view to its suitability for our proposed Hall of Astronomy. There is no museum of astronomy or department of astronomy in the world that compares with that in the German National Museum at Munich, and the most impressive and consequently the most popular piece of apparatus in the whole astronomical department was the new Projection Planetarium. The available space allowed only ten meters for the inside diameter of the dome. The Museum had two lecturers, who together gave nine demonstrations a day. I attended one of these, at which a part of the audience was made up of a large class

INTERIOR OF ZEISS PLANETARIUM AT JENA

The dome is about 50 feet in diameter, with projection apparatus and artificial horizon

INTERIOR OF ZEISS PLANETARIUM AT JENA

The dome is about 50 feet in diameter, with projection apparatus and artificial horizon

LEFT.—Zeiss Planetarium Projection Apparatus in summernight-winterday position, lowest portion of ecliptic above horizon.

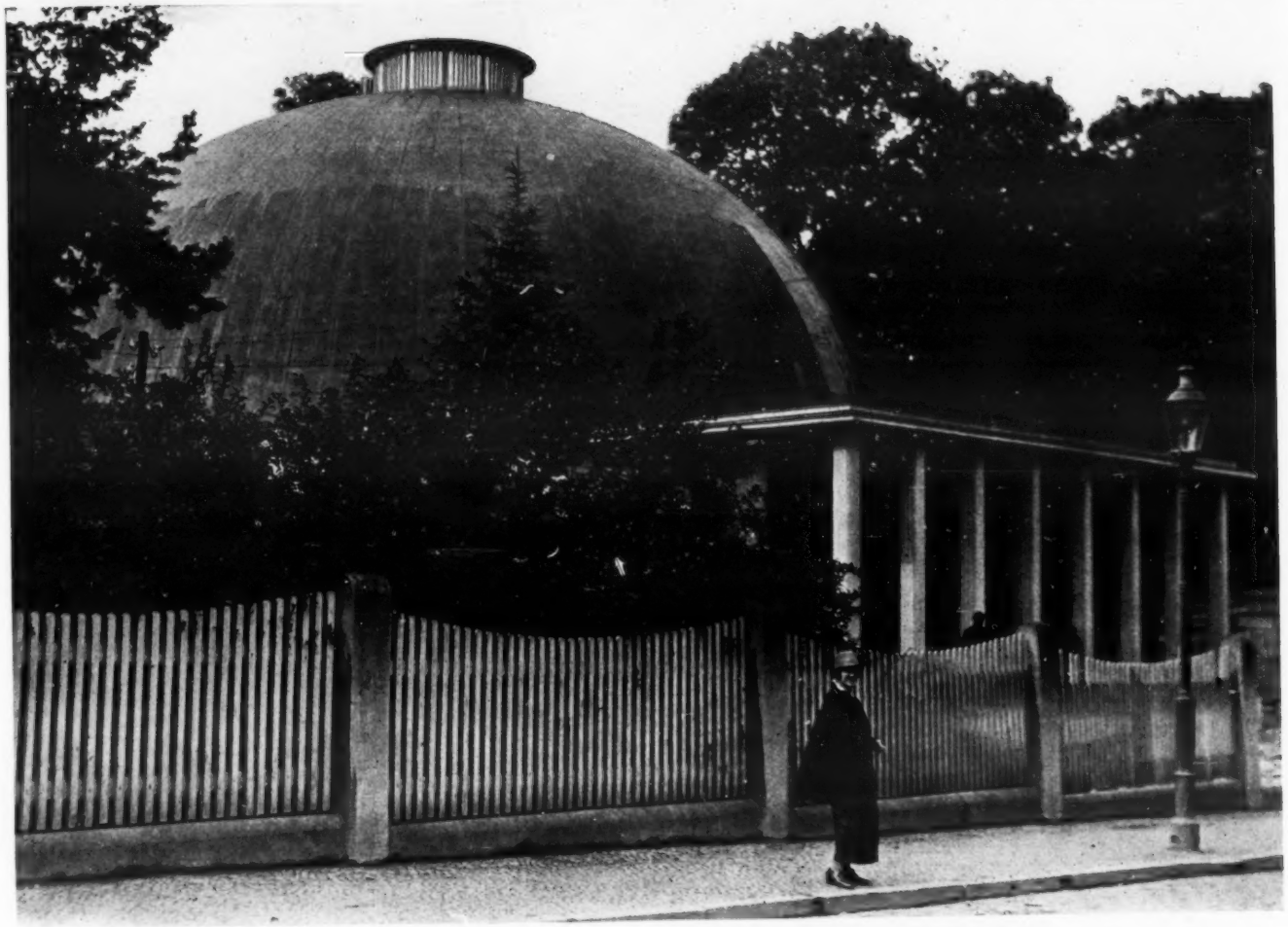
RIGHT.—Zeiss Planetarium Projection Apparatus in summerday-winternight position, highest position of ecliptic above horizon.

In the center of a hollow brass ball at the top, is placed a Nitra lamp of 200 watts, which furnishes illumination for thirty-one projectors that are attached to the outside of this hollow ball and so placed that each one projects a part of the starry heavens. Together they form a continuous picture on the inside of the dome.

The diapositives for these star projectors were made photographically from drawings executed on a large scale which showed every star up to the sixth magnitude. Four thousand five hundred stars were thus located, which is about the number visible to the naked eye. Part of the diapositives are hexagonal in shape and part pentagonal.

To project the Milky Way it was necessary to provide a number of small projectors with the diapositives more or less diffused; it was also necessary to have additional small projectors showing the names of the different constellations.

It was much more difficult to produce the movement of the sun, moon, and planets. This s accomplished by the cylindrical part of the apparatus extending to one side and below the hollow sphere of star-projectors.



ZEISS PROJECTION PLANETARIUM IN PRINZESSINNEN GARTEN IN JENA.
Photograph by Clyde Fisher, September 11, 1925

of pupils from a parochial school accompanied by two or three nuns.

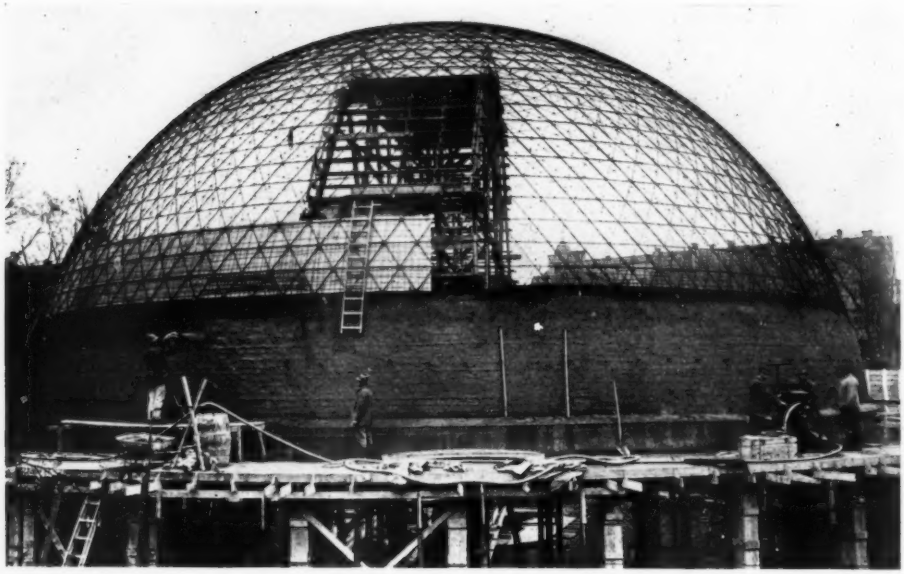
The second Projection Planetarium to be built was located upon the roof of the buildings of the Carl Zeiss Works at Jena, and it was here, before going to Munich, that I first saw the apparatus in operation, and it was here that I made a careful study of the mechanism and its working. The dome is larger than the one at Munich, being sixteen meters or about fifty feet in diameter, and affords seating room for 280 persons, although in the excitement of the first days as many as 600 persons, more than half of them standing, were packed into this dome, and as many as twelve lectures and demonstrations a day were given. The dome is hemispherical in shape and is white inside. In the center is an optical projection apparatus which throws on the inside of the dome images of the sun, moon, all the planets which are visible to the naked eye, and the 4500 fixed stars that are visible to the naked eye, including the Milky Way. These projected images move as the real bodies appear to move in the sky, with the time accelerated due to rotation of parts of the central apparatus, which is so accurately made that it takes care of the precession of the equinoxes. The erratic motions of the planets in the sky as seen by the naked eye from the earth are visualized much more satisfactorily than by the old-fashioned planetarium.

The phases of the moon are just as clearly shown, but most impressive of all is the realistic appearance of the fixed stars, including the Milky Way. In the public demonstrations at Jena the audience was sometimes composed largely of school children. Whether the audience was made up of children or of adults, when the fixed stars appeared, an involuntary "Ah" swept over the assembly and they were spellbound. It seems that no one is prepared for such a realistic representation, and I was no better prepared than others. In short, I was astonished, overwhelmed. The illusion of the immensity of space is perfect. One feels that he is in the great outdoors under a clear night sky. Due to some subconscious imagination, perhaps—at least for some psychological or physiological reason, this artificial sky seems to possess the deep night blue seen in the real sky, and yet there was no blue color on the inside of the dome and none in the projection apparatus. On being congratulated upon the mechanism, Dr. Ing. W. Bauersfeld, the inventor, admitted that the illusion of the immensity of space and the realistic representation of the fixed stars, including the Milky Way, had exceeded even his expectations. And Dr. W. Villiger, head of the department of astronomy in the Zeiss Works, was an unbeliever until the apparatus was finished and demonstrated.

By means of a special set of projectors the names of the constellations can be shown in the sky, and with a flashlight showing an arrow-shaped light the lecturer can point out any star, planet, or other body in the sky.

During several days spent at the Carl Zeiss Works I was afforded every facility for examining this new invention, including several private demonstrations, besides the opportunity of attending a number of public demonstrations. For the latter they have five lecturers, young men with technical training who during part of their time are otherwise engaged in the Zeiss Works. Full notes were made concerning the apparatus, its installation, its demonstration, and its adaptation to our astronomical

ZEISS PROJECTION PLANETARIUM IN PRINZESSINNEN GARTEN IN JENA.
Photograph by Clyde Fisher, September 11, 1925



Spraying liquid concrete on skeleton of dome of Zeiss Planetarium

hall at the American Museum.

In early September eleven of these planetariums had been sold to cities in Germany, and negotiations were in progress with other cities of Europe. Within a few days they expected to close a contract with Vienna. One of the domes in the process of building was seen and photographed in Prinzessinen Park in Jena. In this the dome is twenty-five meters,or a little more than seventy-five feet in diameter, almost exactly the same diameter as the dome planned for our astronomical hall. In the one at Düsseldorf the dome will be thirty meters or more than ninety feet in diameter. For projectional reasons this is considered the maximum limit in size.[1]

[1]At the present time (June, 1926) three Zeiss Projection Planetariums are in operation besides the one in Munich, viz., in Leipzig, in Barmen, and in Düsseldorf. Others are being completed in Berlin, Hamburg, Frankfort, etc., and will be ready in the course of this year. The Planetarium building in the Prinzessinen Park in Jena has been finished since the writer's visit in 1925.

Having read an enthusiastic description of the apparatus, and on account of the confidence inspired by the fact that it was made by the Carl Zeiss Optical Works at Jena, I approached this investigation with a tendency toward a favorable consideration. Determining, however, to hold this inclination in check and to approach the matter with an open mind, I made the examination with care and thoroughness. As a result of this study I am enthusiastically in favor of securing a Zeiss Projection Planetarium for our new astronomical hall. Judging from the experience at Jena and at Munich, I believe it will attract more people to the Museum than anything we have ever had here. When it becomes more widely known, it is sure to come to America. May the first one come to the American Museum of Natural History!

A Nature Trail in the Sky

By FRANK E. LUTZ
Curator, Department of Insect Life, American Museum

FOR more than thirty years I had wanted to be able to recognize at least a few constellations and to call them by name. For more than thirty years I had envied those who could do it, but for some reason or other—either laziness, or an inferiority complex, or lack of proper inspiration, but probably the first—I never really learned any except the two northern "dippers." Then, in March my small boy asked me what a third dipper "up there" was. The question challenged my intelligence and was a call to do my parental best. It does not take as much work as I had thought; even I have learned a few constellations; and it is lots of fun.

"Nature Trail" has come to mean to some of us a path in the woods or fields with labels pointing out a few of the interesting things along it, just as a friend taking a walk with us would do. Let's make a "nature trail in the sky." To fully enjoy this trail, lie flat on your back on Mother Earth, wrapping yourself in blankets if necessary. The effect is often magical, for you seem to float across the sky from one constellation to another.

Before starting on any trail we must get our bearings, and knowing north is very important. Fortunately this is easy in the sky of the Northern Hemisphere, where our present trail is located. Polaris, the North Star, is fairly close to the North Pole of the heavens and will be as long as we live. About 5000 years ago a star in the Dragon's tail was the pole star and 12,000 years from now Vega in Lyra will be the pole star. We shall point out these stars shortly. The celestial north pole moves in a circle that has its center about half-way between Polaris and Vega, one revolution taking about 26,000 years. For our present purpose, however, we may consider that it is a fixed point about a degree from Polaris in the direction of Mizar, the second star from the end of the handle in the Big Dipper; and Polaris is the star at the end of the handle of the Little Dipper. The lip of the Big Dipper points to Polaris.

Mention has just been made of a "degree." Degrees are to the face of the sky, as we see it, what feet or miles are to earthly things, measures of distance. Stars millions of millions of miles apart may seem to us to be very close together and, if one star is nearly back of another from the point at which we stand, the two will to our unaided eyes appear to be one star. From our point of view, it looks as though we are in the center of a huge, hollow glass ball (the sky) that is revolving about us and we can see about half of it at any time. Of course, it is what we are standing on that is revolving but that does not alter appearances. The stars seem to us to be on the shell of this huge sphere.

Do not be discouraged by the following geometry; we shall soon get to sky measuring. There are 360 degrees in a circle. Since we can at any time see about half of any one of the great circles in the sky, the length of a line from some point on the horizon to the horizon opposite the first point is 180 degrees. Clearly, then, if the apparent distance between two stars is $\frac{1}{36}$ of this

distance, the stars may be said to be 5 degrees from each other. But most of us find trouble in estimating small fractions of the distance from horizon to horizon. Therefore, small measuring rods here and there in the sky are convenient. One such measure is the depth of the bowl of the Big Dipper. The two stars that mark the side opposite the handle (the two stars that point to Polaris, the North Star) are about 5 degrees apart. The distance from the tip of the handle of the Big Dipper to the far edge of the bowl is roughly 25 degrees.

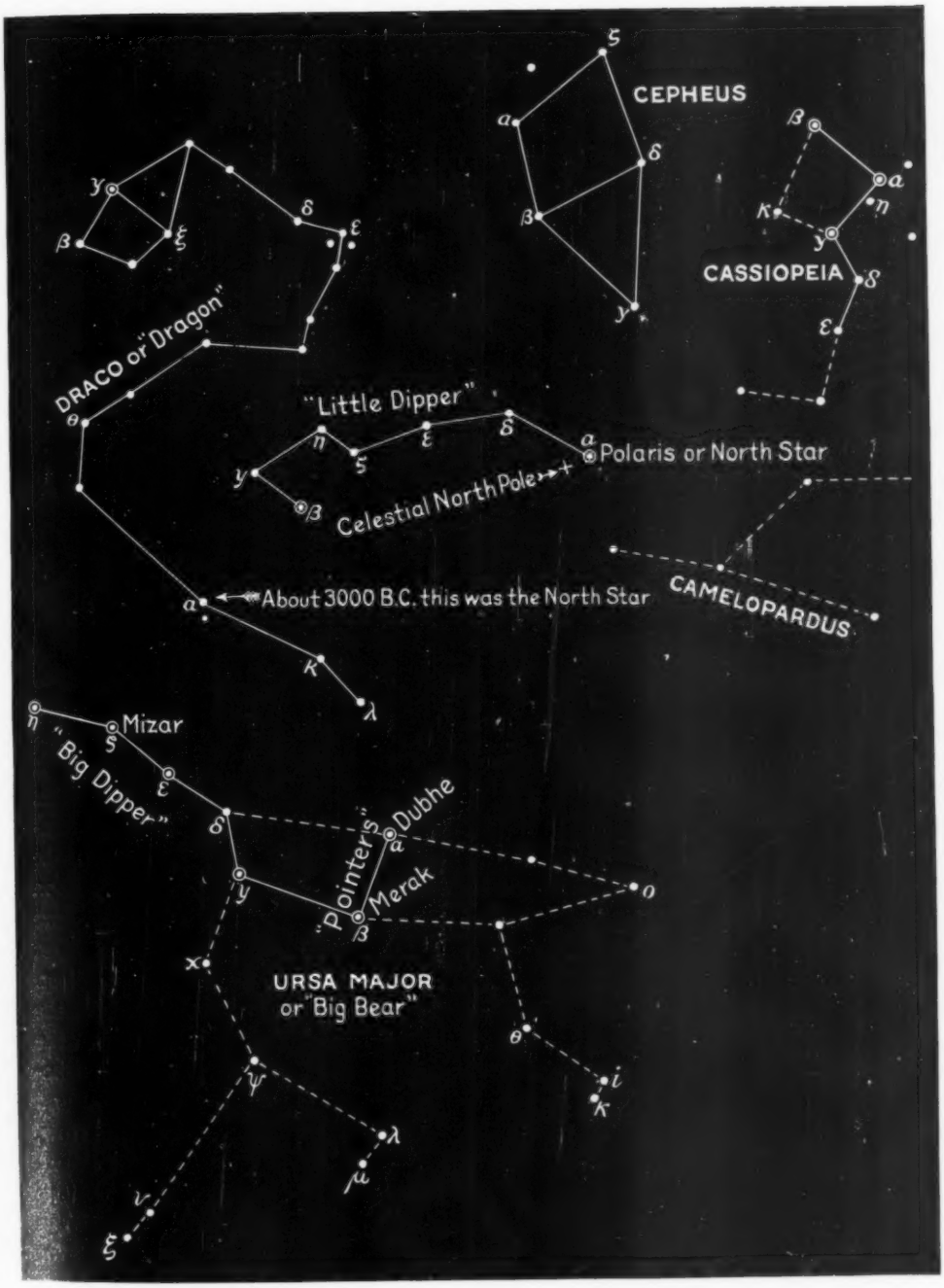
Now, we are ready to take the trail. First, we shall wander about in the region of the Pole and later we shall go to the Zodiac, the celestial menagerie and the stamping-ground of the most far-reaching fraud that ever dignified itself by the name of a "science," astrology. If you must believe in something foolish, believe the stories that I am going to tell you about the Greek gods and goddesses, but do not be so utterly foolish as to think that the positions taken by celestial bodies in their set courses have any connection with the course of your body's destiny, much less of your mind's. The only explanation for the belief in astrology by otherwise intelligent people of the present age is that "Barnum was right."

It so happens that there are five or six rather interesting constellations so near the celestial north pole that people throughout most of the northern half of the world can see them at any hour of a clear night in any season of the year—they do not set below the horizon. To learn these we do not need to wait until certain hours of certain nights, and, knowing them, will help us to find the others. The accompanying map (Map 1) shows approximately the relative positions and distances from each other of these stars. There is no fixed up-and-down to this map because, as our world turns, the map must be turned to keep up with it.

Look at this map, paying special attention to the two "dippers," including Polaris, the North Star. More or less ignore the other stars for the present but turn the map around and around, back and forth, until you can pick out the two "dippers" wherever they are. Then look up in the sky on a clear night in a generally northern direction and there you will see them. That much I have known for thirty years.

Our ancestors either had better imaginations than we have or, being interested in different things, their imaginations took different turns. The constellations that suggest dippers to us suggested bears to them. Accordingly, what we call the Big Dipper is a part of what they called the Big Bear or, in their language, *Ursa Major*. Our little Dipper is their Little Bear or *Ursa Minor*.

Furthermore, the ancient peoples had stories to "explain" the constellations that they recognized. Most of these stories concerned their gods and these gods had some very human traits. Jupiter was king of the Greek gods and Juno was his wife. There was a nymph named Callisto, who interested Jupiter so much that Juno became jealous. Just what happened then is not any clearer than many other family quarrels are. The girl in the case, Callisto, was changed into a bear and the bear was put up in the sky where the stars of Ursa Major, our Big Dipper, mark its position. But, whether Jupiter did it to avoid Juno's jealousy or whether Juno did the changing in revenge and then Jupiter did the rest, is not certain.


CEPHEUS
CASSIOPEIA
DRACO or "Dragon"
"Little Dipper"
Polaris or North Star
Celestial North Pole
About 3000 B.C. this was the North Star
CAMELOPARDUS
Mizar
"Big Dipper"
"Pointers"
Dubhe
Merak
URSA MAJOR
or "Big Bear"

MAP 1

Each of these Bears has an absurdly long tail, the handles of the dippers, and what we call the Big Dipper, for example, is not all there is of *Ursa Major;* other stars belonging to it are shown in Map 1. The letters are the Greek ones by which astronomers designate the different stars of a constellation. In Ursa Major o marks the tip of the bear's nose. The only front foot the beast has (possibly Juno saw to the other one) is at ι and κ; one hind foot is at λ and μ, the other being at υ and ζ.

When stars become very famous they get names as well as letters. Map 1 gives the names of three stars in our Big Dipper. Of these, Mizar, the one next to the end of the handle, is the most important for us. What we call Mizar is itself really a group of stars but to some unaided eyes they look like one; sharper eyes can see two, the fainter of which is called Alcor; and astronomical instruments show others. At any rate, remember Mizar.

Incidentally, Polaris, the North Star, is really a double star, having a companion of ninth or tenth magnitude. The stars that appear brightest to us are said to be of "first magnitude." They are all named in the accompanying maps and marked with rayed dots. Most of the second magnitude stars are marked by dots with circles around them and some are named in these maps. A sixth magnitude star is barely visible to us without a glass.

The Dragon (Draco) lies with his tail between the two "Dippers" or Bears. Opinion is not unanimous as to what dragon this was in life. It may have been the one that Cadmus killed, and then, when he scattered its teeth like seeds, an armed man sprang up from each of them and gave him more trouble. Or, it may have been the one that guarded the golden apples of Hesperides and was killed by Hercules. As we shall soon see, Hercules is now not far away from it in the sky.

The tip of the Dragon's tail is between Polaris and the bowl of the Big Dipper, about eight degrees from the lip of the Dipper (remember that this dipper is about five degrees deep). Following the outline of the beast toward its head we first go parallel to the handle of the Big Dipper until, when just between the bowl of the Little Dipper and the crook in the handle of the big one (the star Mizar) we find the star α of the Dragon. It is the one that was the pole star about 5000 years ago. In other words, the earth is swinging about at such a rate that the end of a straight line continuing its axis until it meets what looks to us to be the face of the sky has moved from near this α star in the Dragon to near the end of the handle of the Little Dipper, our present pole star. The course of the end of this line (that is, the path in the sky of a prolongation of the earth's axis) is a circle. The center of this circle is also the center of the ecliptic, the apparent path of the moon and the location of the Zodiac we are going to see later. But now let us get back to the Dragon or we may get lost.

We followed the outline of the Dragon from the tip of its tail near the lip of the Big Dipper to a point between the handle of that dipper and the bowl of the Little Dipper. Now, still going toward the Dragon's head, we curl around the bottom of the Little Dipper's bowl, then double back so as to make a rough S (turned right for left), as is shown in Maps 1, 2, and 4. The brightest star (γ) of the four which mark the Dragon's head may be roughly located as follows: Imagine a line drawn from Polaris to the end of

the Big Dipper's handle. This line may be considered to be one side of a nearly equal-sided triangle of which the other two sides meet at γ. So, γ is about as far from either Polaris or the end of the Big Dipper's handle as they are from each other.

Cassiopeia is our next constellation. Some see in it a sprawly W; others, taking in one more star (κ), have a chair with an uncomfortable-looking back (upside down in Map 1). However, Cassiopeia was a queen and she is not sitting in that chair but the chair is formed by her bright spots. Her husband, Cepheus, and her daughter, Andromeda, are not far from her. We shall meet them soon.

Well, Cassiopeia, the mother, is there on the side of Polaris opposite the Big Dipper and about as far from Polaris as Polaris is from the Big Dipper. Three of Cassiopeia's stars (α, β, and γ) are bright ones, being of second magnitude. Now meet her husband.

Cepheus, once King of the Ethiopians, is between his wife, Cassiopeia, and the bend in the back of the Dragon. That is rather nice of him and the best that I have been able to learn about him. After studying Map 1 you can probably find him up there but, if you need further help, note that five moderately bright stars form a lop-sided square with a triangle on it, the triangle being on the pole-star side of the square. The top of the triangle is nearly on a line between Polaris and β of Cassiopeia. The following is not usually considered a part of this constellation, but, 4 degrees from ζ, somewhat toward α but outside of the square, is one of the reddest stars that we can see without a glass. Like most red stars, it is a "variable," being brighter at some times than at others.

There are other stars in this general region of the north pole of the sky but we must be going elsewhere, and now we get into the trouble that the constellations we are going to learn are not always visible to us, owing to the way our earth turns around and we with it. First we shall take some constellations of the summer skies at fairly reasonable hours of the evening. Most of Cassiopeia and the bottom of the square of Cepheus are in the Milky Way and, for a while, we shall keep either in the Milky Way or on the same side of it as the stars we have been looking at.

The Milky Way, or Galaxy, looks very much like an irregular and in some places a divided streak of hazy light across the sky. It is a region where there are millions of stars too faint or too far away for our eyes to see them clearly. One explanation is that the universe is shaped like an enormously large Ferris wheel. If such a wheel, miles and miles across, were hung full of lights and we were near its center and looked along the axle of the wheel we would see a large number of lights (stars) but if we looked toward the rim of such an immense wheel we would see many more, most of them so far away that they would be indistinct (the Milky Way).

At any rate, in June the Milky Way is along the eastern horizon at about 9 P.M. and nearly in mid-sky at about 1 A.M. (when the Big Dipper is west of the North Star). In August at 9 P.M. it is in about the same position as in June at 1 A.M. At about midnight of about April first or about 9 P.M. of the middle of May, the Milky Way forms a border along the northern horizon from East to West; in other words, when the Big Dipper is above the North Star.

Start at Cassiopeia, then go along the Milky Way past her husband,

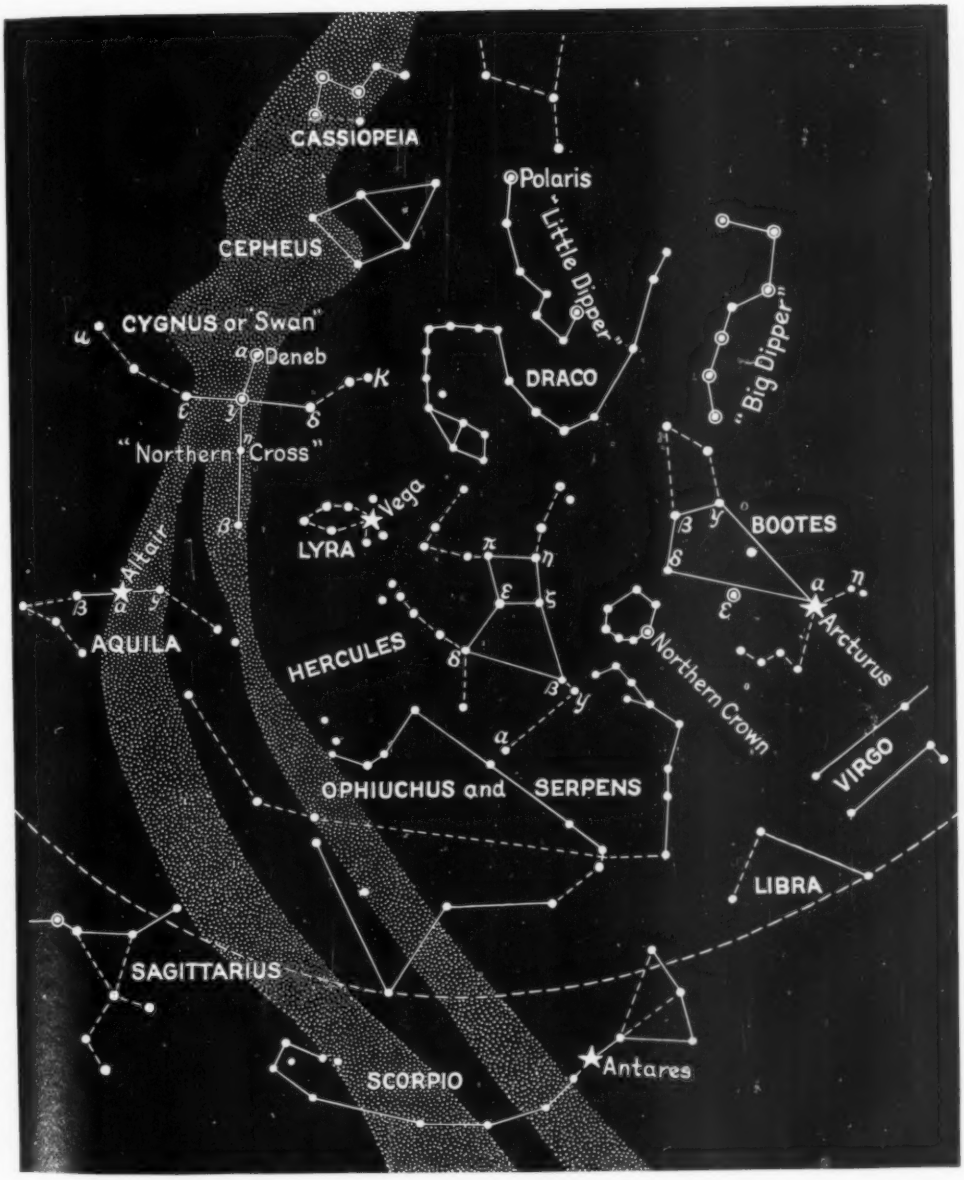
Cepheus, and you will come to the "Northern Cross," a part of Cygnus, the Swan. The head of the Cross (Map 2, α) is toward Cassiopeia and one arm of the Cross (δ) points through the head of the Dragon to the end of the handle of the Big Dipper. Another way of locating it is that the side of the Big Dipper's bowl nearest the handle points toward the foot of the Cross. (Do not include here the very bright star, Vega, that will be mentioned later in connection with Lyra.) From α to β (the whole upright of the Cross) is about the length of the Big Dipper. Taking in the whole constellation, the bill of the Swan is at β and its wings stretch from κ to μ. It seems that Cygnus was a friend of Phaëton, the boy who went joy-riding with the horses of the sun and got into fatal trouble. Cygnus mourned so much that Jupiter changed him to a swan. They had a great way of changing people into animals in those days, and on almost any excuse.

Having seen the Northern Cross, we shall now skip over two constellations (coming back to them soon) in order to see the Northern Crown (Map 2). It is a small (about the size of the bowl of the Big Dipper) but a fairly complete circle of stars that lies on the other side of the Dragon from the North Star. Imagine one line drawn from the bottom of the bowl of the Big Dipper, through the end of its handle, and then prolonged for about the total length of the Big Dipper. It will end at about the Northern Crown. If that is not enough, imagine a second line drawn from the end of the Little Dipper's handle (the North Star), through the bottom of its bowl, through the back of the Dragon and nearly as much farther. It will end and meet the first line at the Northern Crown. This crown was given by Bacchus to his bride, Ariadne. He probably put it in the sky for safe-keeping.

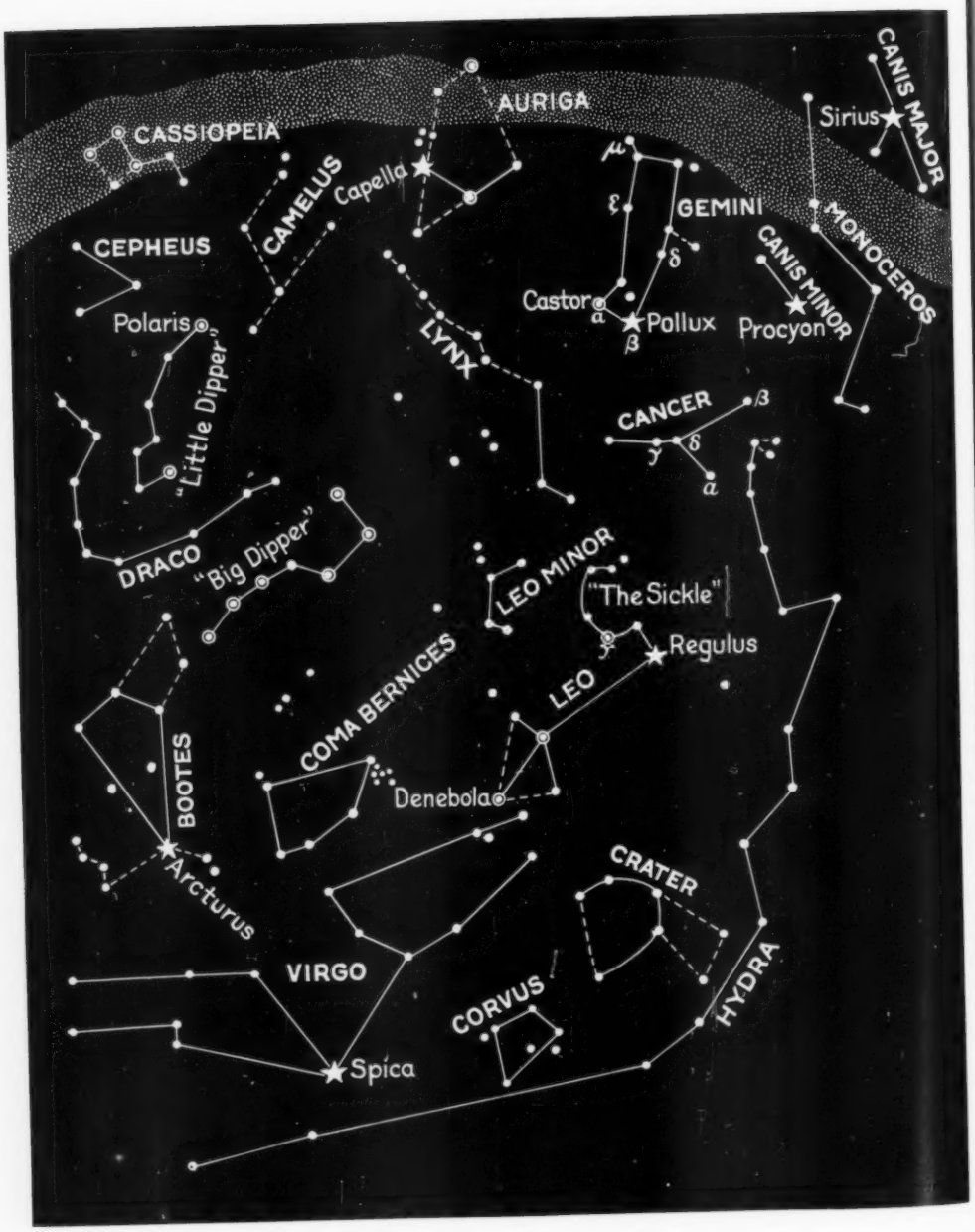
In going from Cygnus to Corona (the Crown) we skipped over Lyra and Hercules. They have not been very easy for me to make out since Lyra seems to me rather indefinite and Hercules rather sprawly.

As for Lyra, let us locate its brightest star Vega and say that the rest of the "Harp" is between it and the foot of the Northern Cross. Vega is very bright (first magnitude) and forms one corner of a nearly equal-sided triangle of which the North Star and the end of the Big Dipper's handle are the other corners. The side of the Big Dipper's bowl that is nearest the handle points fairly close to Vega, as I hinted when trying to locate for you the foot of the Northern Cross. The Harp is supposed to be the one that Apollo gave to Orpheus. Its music not only charmed men and beasts but made even trees and rocks get up and move around. More than that, when the wife of Orpheus died and went "where Pluto held his sway," Orpheus followed her and played so sweetly that Pluto let her out. By the way, it is said that Vega is 160 millions of millions of miles from us but approaching at the rate of 500 miles a minute. It is at least 30 times as bright as our sun and, as was said before, will be our descendants' north star 12,000 years from now.

I cannot help you much with Hercules except to say that a part of him is between Vega and the Northern Crown. Perhaps you will see four stars there that mark the corners of a rough square. The two that are farther from the North Star than the other two are his belt; the closer two are in his legs, and his feet are near the Dragon


CASSIOPEIA
Polaris
Little Dipper
CEPHEUS
CYGNUS or "Swan"
Deneb
DRACO
"Big Dipper"
"Northern Cross"
Vega
LYRA
BOOTES
Altair
AQUILA
HERCULES
Arcturus
Northern Crown
VIRGO
OPHIUCHUS and SERPENS
LIBRA
SAGITTARIUS
SCORPIO
Antares

MAP 2


CASSIOPEIA
AURIGA
CANIS MAJOR
Sirius
CAMELUS
Capella
GEMINI
CEPHEUS
MONOCEROS
CANIS MINOR
Castor
Pollux
Procyon
Polaris
LYNX
"Little Dipper"
CANCER
DRACO
"Big Dipper"
LEO MINOR
"The Sickle"
Regulus
COMA BERNICES
LEO
BOOTES
Denebola
Arcturus
CRATER
VIRGO
CORVUS
HYDRA
Spica

MAP 3

that he may have killed in addition to doing many other wonderful things. Perhaps Maps 2 and 4 will help you to get his various parts together.

Going on the other side of the Northern Crown (Corona) from Hercules we find Boötes. Boötes is a plowman and some have called the Big Dipper his plow, but the constellation looks more like a kite with a very bright, first-magnitude star (Arcturus) where the tail would be fastened and with its head lying near and being pointed at by the handle of the Big Dipper. (See Maps 2 and 3). Arcturus is said to be about 250 millions of millions of miles away and approaching us at the rate of 150 miles per minute. It is about a million times as large as our sun. We deal with large numbers in the heavens. Another name of this constellation is Arcas. If you look up the story of Arcas, the son of Callisto, you will see why this constellation is near the Great Bear—why, that is, according to mythology.

Moving farther away from the North Star, we come to a Snake (Serpens). It has its head near the Crown (Corona) and is being held by a man (Ophiuchus) who is at the head of Hercules. The combination is in honor of Æsculapius, the god of medicine (note the emblem of the medical corps in our army), but we shall not stop to see the doctor and there is a much better snake farther on.

Still going away from the North Star in this same direction we come to the Scorpion in the zodiac along the ecliptic; and the ecliptic is a very important thing in matters of the sky. Let me quote from Howe here so that if it is wrong you can blame him.

"The zodiac, or zone of animals, is a belt sixteen degrees wide, which extends around the sky like the stripe on a croquet ball. From antiquity onward much attention has been paid to the constellations in it. Imagine that a line from the center of the sun to the earth's center is prolonged through the earth and extended until it meets the celestial sphere.

"While the earth travels round the sun in its annual journey, the extremity of this line traces a circle on the celestial sphere. The name of the circle is 'the ecliptic.' To an eye situated at the sun's center the earth would appear to travel around the ecliptic. To an eye placed at the earth's center the sun would similarly appear to course along the ecliptic, taking a year to make the complete circuit, passing through the zodiacal constellations in succesSion. The ecliptic lies in the middle of the zodiac, which extends eight degrees each side of it. As we watch the sun, moon, and planets, they always appear to lie in the zodiac."

Since the ecliptic is a sort of a circle and the zodiac is a circular zone, they have neither beginning nor end and we can break in at any point. But, since it is not very comfortable to go stargazing just for the fun of it before about the middle of May, we shall start with that member of the zodiac that sets in the West at about 9 P.M. then, the Gemini or "Twins." However, I suggest that you do not start on this tour of the zodiac and the side trips that will be taken in connection with it until you have become well acquainted with what has gone before, especially with those stars shown in Map 1. We are going to use the constellations already mentioned as landmarks—or "skymarks." When on a new trail, one should be able to recognize such things and, furthermore, if you learn merely what has already been pointed out you will know more about the sky than most people do.

The Twins, Castor and Pollux, may be found as follows. Starting with Mizar, the bright star that is next to the end of the Big Dipper's handle, follow a line from it diagonally across the Big Dipper's bowl to the two stars which lie in the front foot of the Bear (see page 414); then extend this line about 25 degrees (about the total length of the Big Dipper) farther. That will bring you to the Twins. The rest of the constellation is on beyond them (between them and the Milky Way) and may be recognized from Maps 3 and 5.

These boys were interesting brothers. Pollux, represented by the brighter of the two stars, one of first magnitude, was immortal; but Castor, represented by a fainter star (really a double one) near him and on the side toward Cassiopeia, was mortal. Being mortal, Castor died, and Pollux was so grieved that he wanted to die too but, being immortal, he could not do so without special permission. Jupiter refused this permission but compromised by allowing Castor to spend one day with Pollux on Mt. Olympus, and Pollux to spend the second with Castor in Hades, and so on.

The next constellation on the ecliptic, following the order in which they arise in the East, is Cancer. This does not mean that Cancer is always east of Pollux as we see them in the sky—a very confusing thing due, among other things, to the fact that the ecliptic is not parallel to the celestial equator. I am far from understanding this fully, but twirling the disc of the very useful "Barritt-Serviss Star and Planet Finder" has helped much.

Cancer in the sky is not a disease but an animal, a crab. The stock explanation of why this constellation was called a crab does not appeal to me very much and my own private explanation may not be true, so I shall give neither, although I may say that each is connected with the habit crabs have of going sideways. The particular crab which this one is said to be is the one that pinched Hercules when that famous hero was fighting the nine-headed hydra.

None of the stars of Cancer is of more than fourth magnitude. Five of them (Maps 3 and 5) outline a Y and there is a pair by the side of the Y's fork. A line from Polaris (the North Star) through the tip of the Big Bear's nose and prolonged 40 degrees ends near the center of the Y. There is a test for you. The tip of the Big Bear's nose is at the second star beyond the lip of the Big Dipper nearly on a line starting from where the handle joins the bowl, going through the bowl's lip and then prolonged 15 or 20 degrees. Remembering that the length of the Big Dipper is about 25 degrees, you can get that and, clearly, 40 degrees is 1⅗ times 25.

One reason for working hard to find this constellation (March and April are good months in which to start hunting for it; during the summer it sets too soon) is that one of the most ancient of weather signs concerns it. Two stars in the middle of the Y are called the Asses and between them is a cluster of stars—to our eyes often not more than a faint glow of light—properly called Praesepe. It's English names are Beehive and Manger. If the Asses thought that it was Manger and found that it was Beehive, I imagine they would kick, but that has nothing to do with the weather. Here it is from a Greek poet, Aratus:

"A murky manger with both stars
Shining unaltered is a sign of rain.
If while the northern ass is dimmed
By vaporous shroud, he of the south gleam radiant,
Expect a south wind. The vaporous shroud and radiance
Exchanging stars harbinger Boreas."

Boreas is the north wind but I do not vouch for the prophecy any more than I sponser that translation as good poetry. Also, another thing that I merely pass on to you is that here is the "gate of men" through which souls descend into human bodies and return to regions above the sky when they leave those bodies.

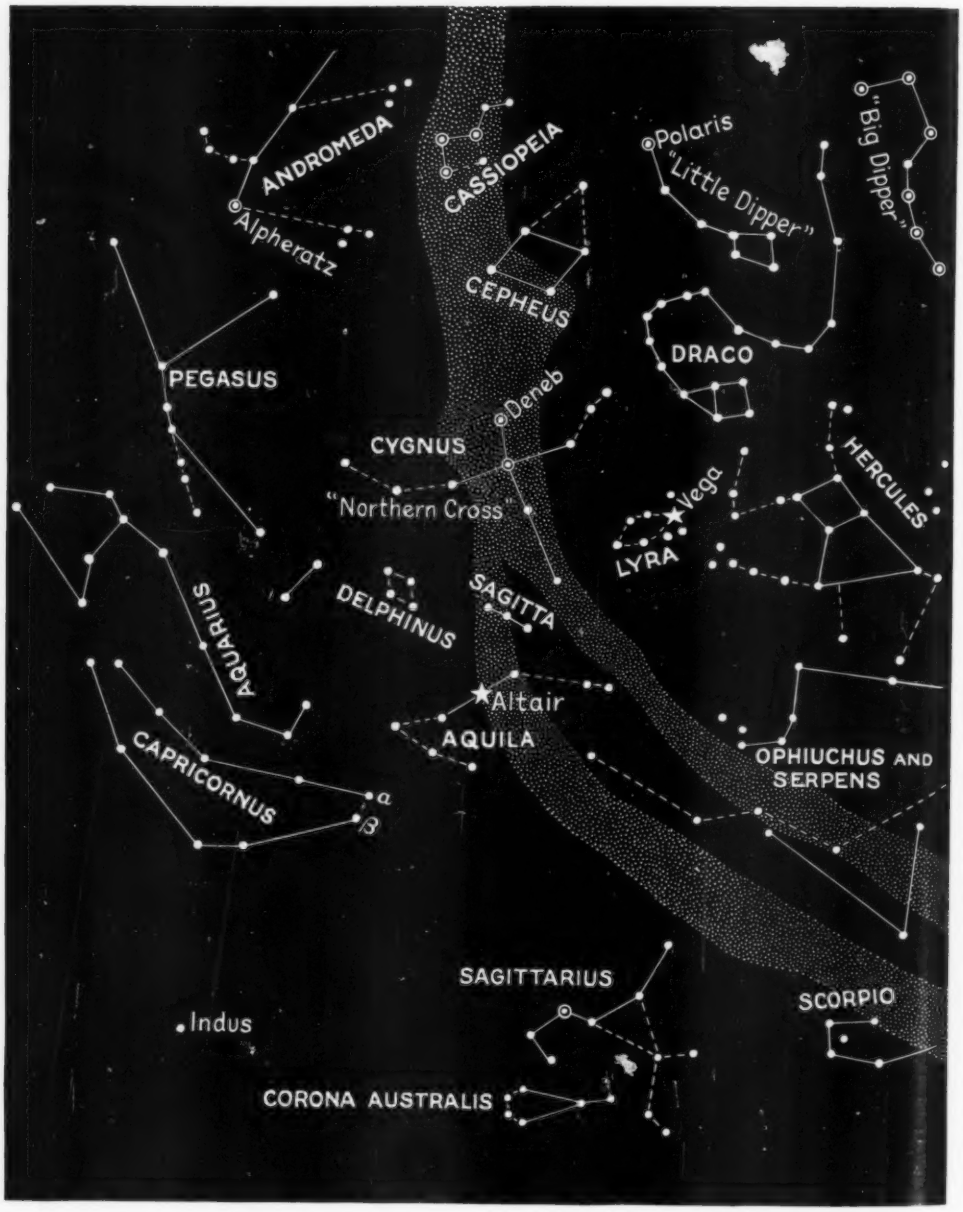
Leo, the Lion, is the next in line as we move along the zodiac. There seem to be two constellations here, a sickle and a triangle (Map 3). A line from Polaris through the bowl of the Big Dipper, and then continued, passes through the triangle, which is more or less (depending on how high up the constellation is) east of the sickle. If you can locate μ in one of the hind feet of the Big Bear (see Map 1) you can imagine a line from Polaris through it which, if extended 22 degrees will meet γ of the sickle but, knowing about where to look for these things, you can probably locate the sickle more easily by the first-magnitude star, Regulus, at the free end of its handle. The star at the corner of the triangle most distant from the sickle is Denebola and the distance from Regulus to Denebola is about 25 degrees or about the total length of the Big Dipper.

The Virgin (Virgo) reclines along the celestial equator about where the ecliptic crosses it on this side of the celestial north pole. Of course, this does not help you to find Virgo but, if you learn to recognize Virgo, you will know about where that point is. Her head is near Leo and she stretches out beyond Arcturus, the Virgin being not far from that famous star (see Map 3). She has one first-magnitude star, Spica, which is really made up of two revolving about each other—many of what seem to us to be single stars are not really so. A line from the North Star through about the middle of the handle of the Big Dipper and continued nearly twice as much farther will end near Spica. An easier way to find it (also a check on the other way) is that the long side of the "kite" in Boötes that is near the Crown points almost directly at Spica. Having located this star, you can probably link up the others by help of Map 3. This virgin's name on earth was Astræa. She was famed for her kindness and is said to have been the last of the immortals to leave the earth at the close of the Golden Age.

Now let us go beyond the zodiac to see the immense snakelike constellation, Hydra (Map 3). Those of us who do not care to stay up after midnight will have to look after the middle of February if we wish to see all of it; by about the end of June it sets too soon to be seen well. The head is near Cancer on the opposite side from the North Star; and the next to the last star in its tail is near Spica, a long stretch roughly parallel to and (in the North) near the horizon. Between it and the Virgin is Corvus, the Crow, pecking at Hydra.

The next constellation of the zodiac is Libra, the Balance (Map 2). It is a small one that used to be considered to be the claws of its succeeding neighbor, the Scorpion, but scorpions can lose claws without much apparent discomfort. A line from the North Star running through the far bottom corner of the Little Dipper's bowl and continued between the Crown and Boötes will finally meet Libra, the Crown being about half-way between it and the bowl of the Little Dipper.

The Scorpion (Scorpio) does not get its tail completely out from under the southeastern horizon before about midnight in May and about nine o'clock in early July. The creature stretches


ANDROMEDA
Alpheratz
CASSIOPEIA
CEPHEUS
Polaris
"Little Dipper"
"Big Dipper"
DRACO
PEGASUS
Deneb
CYGNUS
"Northern Cross"
Vega
LYRA
HERCULES
AQUARIUS
DELPHINUS
SAGITTA
Altair
AQUILA
CAPRICORNUS
α
β
OPHIUCHUS AND SERPENS
SAGITTARIUS
SCORPIO
Indus
CORONA AUSTRALIS

MAP 4

right across the Milky Way. A line from the North Star running along that side of the square in Hercules that is nearest the Crown and extended more than as much again will just about meet the only first-magnitude star in this part of the sky (Map 2). It is Antares in the Scorpion. With it, the Milky Way, and Map 2 as guides, you can doubtless make out the rest of the Scorpion.

I do not know what to think about the justice of everything connected with this Scorpion's affairs. Orion was a mighty hunter but not a conservationist. He started out to kill all of the beasts of the field. That was not right, of course; and the earth sent the Scorpion to sting him, which it did and killed him. Æsculapius, the mighty physician, was bringing him back to life, but Jupiter hit the doctor with a thunderbolt and that was the end of that. The Scorpion is now in a nice bright place in the zodiac, even though it is rather close to the horizon for us to see, and we shall meet Orion later.

We have now examined all of the principal constellations and some of the lesser ones that are in our northern sky between the arms of the U-shaped Milky Way, the U that stretches along the northern horizon at, say, 9 P.M. in the middle of May or at midnight in the latter part of March. As the season advances, things swing around until all but the tail of the Scorpion is under the western horizon at midnight on the first of August or at 9 P.M. in the middle of September. Then we have an entirely new set of stars which are to be seen on the other side of the Milky Way from the North Star. We shall look at them now.

Sagittarius, the Archer, is in the zodiac near the Scorpion's tail. Some of its stars form what is called a Milk Dipper. (See Map 4.) A line from the North Star through Vega just misses the handle of this, going between it and the Scorpion. A line from the middle of the W in Cassiopeia through the middle of the Northern Cross (Cygnus) meets the bowl of this Milk Dipper.

Incidentally, this last line, just after it left the Northern Cross, went near a first-magnitude star, Altair, in the constellation of Aquila, the Eagle (Map 4). Altair is near the edge of the Milky Way. The eagle is probably the one that stood at the side of Jupiter's throne. It is too bad that it is not in the zodiac. On the other side of Sagittarius, so near the horizon that it is often not easy to see, is the Southern Crown. It is close to the bowl of the Milk Dipper of Sagittarius and looks like a round-headed kite with four stars in the curve. You may be able to see it in the South at, for example, about 9:00 P.M. in the middle of August or about midnight in early July.

The next two members of the zodiac are best studied together because the first of them, Capricornus, the Goat, is overlapped by the rather extensive Aquarius, the Water Carrier. Look at Map 4 and then orient yourself in the following way. A line from the North Star through the star marking where the arms of the Northern Cross join its upright, if prolonged an equal distance, about meets α of Capricornus. Good eyes can see without a glass that this star is double. The one which is near it, β, is also double but it takes a glass to see this. The "pointers" of the Big Dipper form a line which goes through the North Star and, extended, just misses the W of Cassiopeia. Extend it a little more than as much again and you will strike near the far end of Aquarius (Maps 4 and 6). The first-magnitude star in that region but in the

direction of Capricornus is Fomalhaut. It is in the constellation of the Southern Fish, not the Fish that is in the zodiac.

As to the mythology of Capricornus, the Goat, Howe says that one who tries to study it "may be pardoned for wishing that Jupiter had given the goat a nice pasture in his back yard and kept it out of sight of mortals." The Water Carrier is said to have been Ganymede, the cup-bearer of the gods, but, according to the stories I used to read, it was not water that Ganymede had in his cups.

Pisces, the Fishes of the zodiac, are not very striking, but they lie along the ecliptic, almost meeting and somewhat overlapping Aquarius (Maps 5 and 6). A line from Polaris (the North Star) through the nearest star in Cassiopeia's W will cross Pisces near the eastern end (the last to rise and set) of it. But perhaps the best way to learn Pisces is to learn the constellations between it and the North Star first.

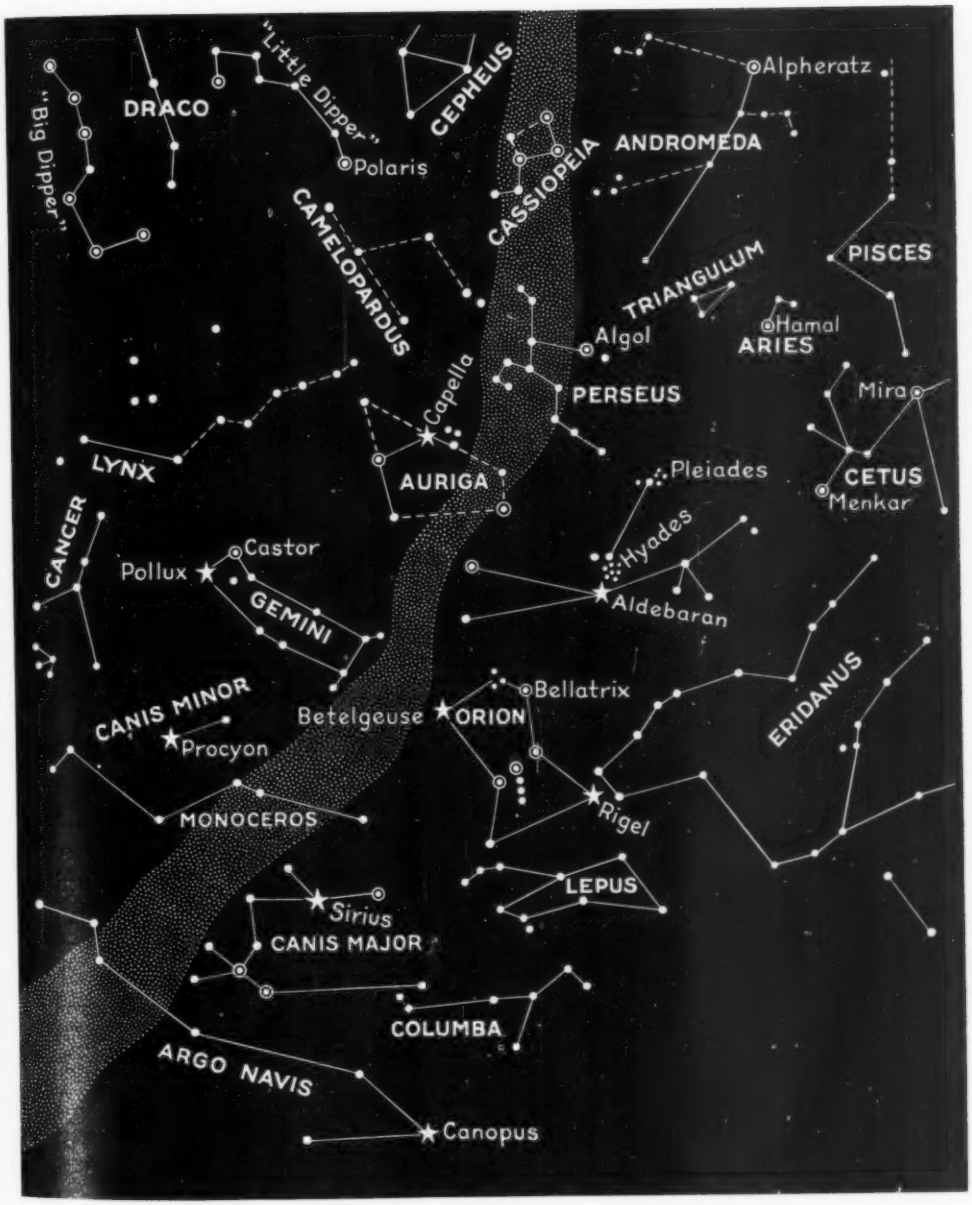
We are now in the eastern heavens at about midnight in the end of July or about 9 P.M. in the middle of September. In that case the Pleiades have not yet arisen. Or, if you prefer cold nights, we are in the western heavens at about midnight in November or about 9 P.M. during the Christmas holidays and the Pleiades are right above us.

First find Andromeda (Maps 4, 5 and 6) and especially locate her α, a star known as Alpheratz, by drawing a line from Polaris through β in Cassiopeia (what would be the right-hand upper star of her W if the W were right side up) and prolonging it an equal distance. A line from Polaris through the left-hand upper star of the W and prolonged an equal distance ends not very far from the other side of Andromeda.

We have mentioned this girl before and pointed out Cepheus, her father, and Cassiopeia, her over-proud mother. If Perseus is still below the eastern horizon with the Pleiades we shall have to wait an hour or so for him to come up but, otherwise, we have all of the actors in a rather interesting drama, the *personæ* of which are shown in Map 6. Read about it in Bulfinch's *Age of Fable* or in some other good book. In bare outline it is as follows.

Cassiopeia had angered the Nymphs of the Mediterranean by saying that they were not so beautiful as her family (herself according to some authorities, and her daughter according to others, but probably both). The Nymphs threatened to kill off all of the Ethiopians of which Cepheus was king, but compromised on having Andromeda chained to a rock so that Cetus, a sea monster, could eat her. This Cepheus did and things looked bad for Andromeda, when Perseus came along on Pegasus, a horse with usable wings. This horse had just been born from the blood that dripped from the head of Medusa, a snaky-headed Gorgon killed by Perseus. Medusa is not in this story except that she unintentionally furnished the horse and that Perseus had her head with him as a trophy.

They did not draw the color-line in those days and Perseus agreed that if he could marry Andromeda, who, being an Ethiopian, was black, he would save her from Cetus. That was what happened, though he had a hard fight. There was more trouble at the wedding, for Andromeda's former suitor, Phineus, came with a large number of his friends. All of them, including Phineus, were turned to stone when Perseus held the head of Medusa in front of them and they did not get into the sky, but the family is there, including Pegasus, the horse. Cetus, the Sea-monster, is also there near that part of


"Big Dipper"
DRACO
"Little Dipper"
Polaris
CEPHEUS
CASSIOPEIA
Alpheratz
ANDROMEDA
CAMELOPARDUS
TRIANGULUM
PISCES
Algol
Hamal
ARIES
PERSEUS
Capella
Mira
LYNX
AURIGA
Pleiades
CETUS
Menkar
CANCER
Castor
Pollux
Hyades
GEMINI
Aldebaran
CANIS MINOR
Bellatrix
Betelgeuse
ORION
ERIDANUS
Procyon
MONOCEROS
Rigel
LEPUS
Sirius
CANIS MAJOR
COLUMBA
ARGO NAVIS
Canopus

MAP 5

the horizon which, on the northern shore of the Mediterranean, is the sea. Even so, the Nymphs had a bit of revenge, for Cassiopeia hangs in the sky head-down obout half o˚ the time.

Now for Pegasus. Perhaps by using Alpheratz of Andromeda as one corner, you can see a rough square about 15 degrees on a side between Cassiopeia and Aquarius (Maps 4 and 6). The other three corners of this square are the principal stars in Pegasus, the rest of the horse being in the direction of the Northern Cross and Capricornus.

Cetus (called a Sea Beast but it must have been more than a whale) is on the other side of the zodiac beyond the Fishes, part of it really coming into the zodiacal region. Map 6 will help you. Mira varies greatly in brightness and, although usually quite faint now, it was a first-magnitude star in the eighteenth century.

Perseus and Cassiopeia are near each other in the glory of the Milky Way near Andromeda, who isn't. A line from the far corner of the Little Dipper's bowl through the North Star nearly meets Algol on the other edge of the Milky Way (Maps 5 and 6). The right-hand line of Cassiopeia's W, continued "below the line" also about meets this star, which is the most interesting one Perseus has. It is also called the Demon and varies from second magnitude to fourth and back again to second in less than three days.

Near Perseus and between him and the Twins, Castor and Pollux, is a first-magnitude star, Capella. It is in the constellation of Auriga, the Charioteer (Maps 3, 5 and 6).

Now we shall return to the zodiac for a bit. Next to the Fishes is Aries, the Ram. Properly speaking, this is where the zodiac starts but it was more convenient for us to start elsewhere. A line from Polaris to Andromeda (see Maps 5 and 6) and prolonged nearly 20 degrees ends at α of Aries, one of the three stars that form the Ram's head. His body consists of faint stars between it and the Pleiades. This is said to be the celebrated ram with the golden fleece that was the reason for one of the first zoölogical expeditions, the Argonautic.

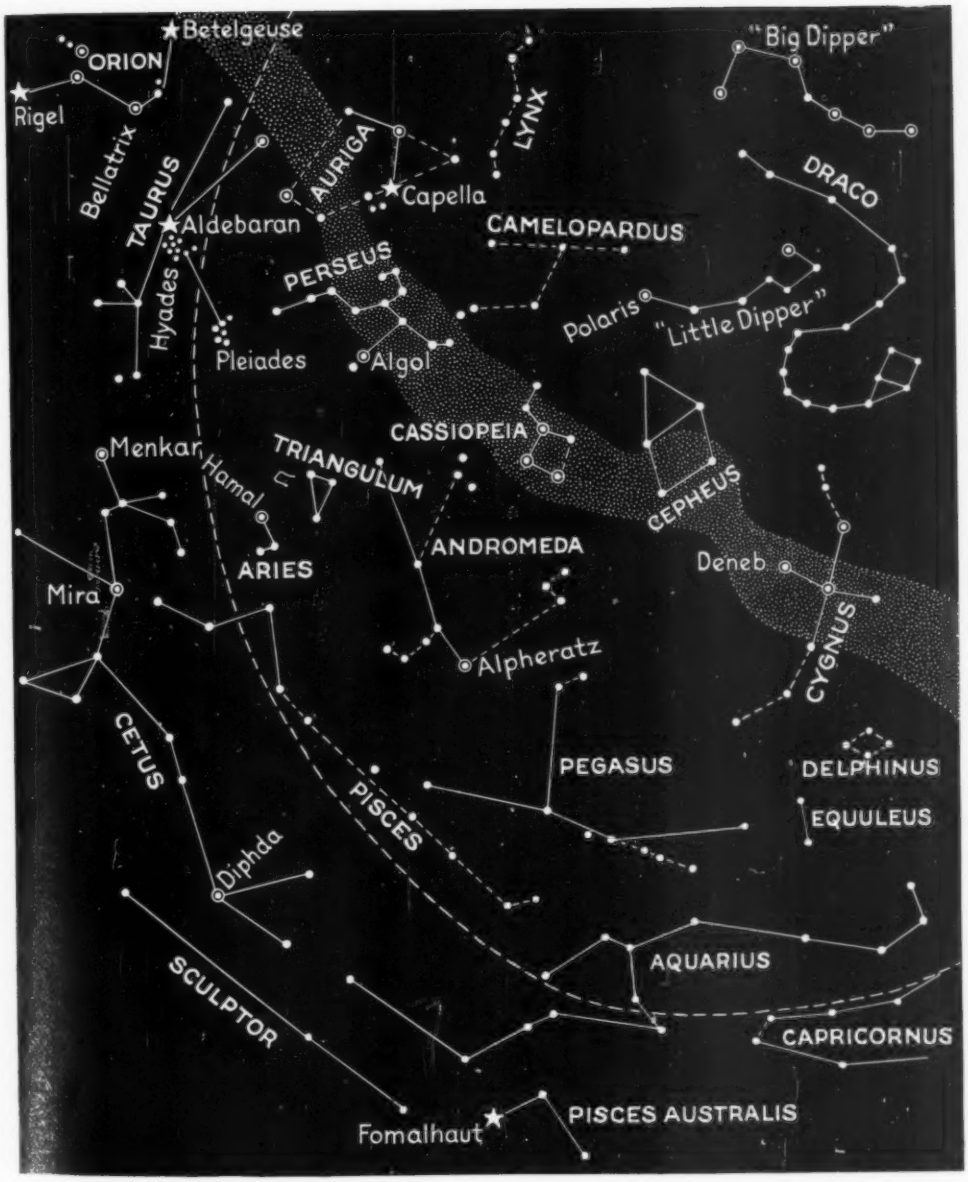
Finally, so far as the zodiac is concerned, we have Taurus, the Bull (Maps 5 and 6). A fine first-magnitude star, Aldebaran, is there. A line starting from the middle of the handle of the Big Dipper, going above its bowl and then through Capella, finally meets Aldebaran. (See Maps 5 and 6 and what follows.)

The Pleiades and the Hyades are two groups of stars that are associated with the constellation of Taurus. Tennyson wrote:

> Many a night I saw the Pleiades, rising through the mellow shade,
> Glitter like a swarm of fire-flies tangled in a silver braid.

Orion is said to have fallen in love with the Pleiades, who were daughters of Atlas, and chased them. To save them, according to this story, Jupiter turned them into pigeons and then put them in the sky. Although there were seven, one is said to have left her place so that she might not behold the ruin of Troy. Another explanation of the missing girl is that she fell in love with a mortal and hid herself in shame. The Hyades were nymphs who took care of Bacchus in his youth.

Whatever may be the facts of the case about the Pleiades, Orion is not far from them now—just the other side of Taurus (Maps 5 and 6). He certainly is well fitted out with fine stars, Betelgeuse, Bellatrix, and Rigel, especially. Pollux (of the Twins), Betel-


Betelgeuse
ORION
Rigel
Bellatrix
TAURUS
Aldebaran
Hyades
Pleiades
AURIGA
Capella
LYNX
"Big Dipper"
DRACO
CAMELOPARDUS
PERSEUS
Algol
Polaris
"Little Dipper"
CASSIOPEIA
CEPHEUS
Menkar
Hamal
TRIANGULUM
ARIES
ANDROMEDA
Deneb
Mira
Alpheratz
CYGNUS
CETUS
PEGASUS
DELPHINUS
EQUULEUS
PISCES
Diphda
AQUARIUS
SCULPTOR
CAPRICORNUS
Fomalhaut
PISCES AUSTRALIS

MAP 6

geuse, and Rigel are about in a line. Another way of locating them is that there is a rough square with the Milky Way going through it. Capella (of Auriga) and Pollux are on the North Star side of the Way and Aldebaran (of Taurus) and Betelgeuse are on the other side. Also, Aldebaran, Betelgeuse, and Rigel form a nearly equal-sided triangle. But in all of this do not get confused with Orion's two dogs, one on each side of the Milky Way, below the Twins and Orion.

Canis Minor, the Little Dog, has but two bright stars, one (Procyon) of first magnitude (See Maps 3 and 5). Canis Major, the Big Dog, is richer in stars and includes *the* Dog Star, Sirius. Sirius is in the dog's head as it faces its master. It is the brightest of the fixed stars and can readily be found by prolonging the line formed by the three stars in Orion's belt toward the Milky Way. Another way of locating it, if you care to go clear across the sky, is that the outer part of the Little Dipper's bowl points to it, the line passing to the west of Pollux and Procyon.

So, we have swung the seasons in the sky and have glanced at all of the principal constellations of the Northern Hemisphere. It is not the purpose of a Nature Trail to tell everything. Perhaps I have told too much here; you may be confused. If so, go back to the beginning and learn the first half-dozen that can be seen at almost any time of any night of any month. Later on, you will be ready to do a nightly dozen and it will be worth while.

NOTES

ADVISORY COMMITTEE ON ASTRONOMY

In developing the plans for the Museum's Great Astronomical Hall and for the exhibits which will interpret this subject to the public, the Museum is receiving invaluable assistance from William Wallace Campbell, Sc.D., LL.D., director of Lick Observatory; George Ellery Hale, Ph.D., Sc.D., LL.D., honorary director of Mt. Wilson Observatory; Samuel Alfred Mitchell, Ph.D., Director of Leander McCormick Observatory; Henry Norris Russell, Ph.D., director of Halsted Observatory; Howard Russell Butler, M.F.A., who have consented to serve as the Advisory Committee on Astronomy.

DISTINGUISHED GUESTS

THE CROWN PRINCE OF SWEDEN, GUSTAVUS ADOLPHUS, and the CROWN PRINCESS LOUISE visited the American Museum of Natural History on June 8. The members of the Board of Trustees, the director, and the curators, who were on hand to receive the royal party, were much pleased with the genuine interest and wide knowledge which they manifested. Among the halls visited during an intensive two hours' tour were: Morgan Gem Hall, Peruvian Archæology, Preliminary African Hall with especial attention to the Akeley gorillas, Flying Bird Dome, Habitat Groups of North American Birds, Dinosaur Hall, Age of Man Hall, and Pro-Astronomic Hall.

Mr. Robert Woods Bliss, American Minister to Sweden, was a member of the visiting party. The Crown Prince and the Crown Princess have made a deep and favorable impression upon the members of the Museum staff as they have upon the American people generally.

CENTRAL ASIATIC EXPEDITION

Roy Chapman Andrews, leader of the Central Asiatic Expeditions, has cabled the American Museum of Natural History that although he has been able to get the camel caravan safely out of the Chinese war zone and into Mongolia, the Expedition party has not yet been able to take the field. He stated that the camel train had been commandeered three times by the soldiers, but after careful negotiations, was at last passed through with a military escort. The members of the Expedition are at present in headquarters in Peking awaiting a change in the military situation. At a conference the members decided that there was still time for reconnaissance work, and inasmuch as the Expedition is completely organized, every reasonable attempt will be made to carry out the plans for this summer. It is desirable to proceed to the western region south of the Altai Mountains and, if the fossil deposits warrant, a working force will be sent there next year.

While at headquarters, the members of the Expedition have been busy preparing fossil material already collected, so that practically no time has been lost. However, the delay in starting for Mongolia has been a disappointment. Owing to this delay, it is hardly probable that any extensive discoveries can be made this season, but it is hoped that by means of a hasty survey a region may be selected that will next year yield results for which such strenuous efforts have been made.

Mr. Andrews states that representatives of the Mongolian Government have called upon him in Peking with a formal invitation for the Expedition to return to outer Mongolia. They promised to give all possible aid in the prosecution of the work, and most cordial relations were established.

PRESIDENT HENRY FAIRFIELD OSBORN has been spending the last twomonths in England engaged in palæontological research. In an address before the Geological Society of London, Professor Osborn discussed the geological significance of the discoveries made this spring in the Gobi Desert by the Third Asiatic Expedition under the leadership of Dr. Roy C. Andrews. These discoveries have verified a prediction made by Professor Osborn as long ago as 1900 that the unknown high plateau region in Central Asia would prove to be the chief center of origin and distribution of mammalia from which radiated all animal life to the continents of Europe and North America.

THIRD PAN-PACIFIC SCIENCE CONGRESS

Mr. Walter Granger, associate curator in palæontology, and Mr. N. C. Nelson, associate curator of archæology, have been appointed official representatives of the American Museum of Natural History to the Third Pan-Pacific Science Congress to be held in Tokyo, Japan, October 27 to November 9, 1926.

BIRDS

Dr. Frank M. Chapman and Dr. Robert Cushman Murphy were official representatives of the American Museum of Natural History at the International Ornithological Congress held at Copenhagen, May 24–29, 1926. These American delegates were especially honored by the authorities in charge of the program, who engaged a theater and invited the scientists of Copenhagen to attend a special meeting at which Doctor Chapman spoke on "Bird-Life of Barro Colorado and Chile," and Doctor Murphy spoke on the "Bird-Life of Peru."

Doctor Chapman went from Copenhagen to London, where he addressed the Royal Geographical Society on "Darwin's Chile" (it being just one hundred years since the survey was inaugurated in which the "Beagle" took part). He also spoke before the Zoological Society on "Barro Colorado," and before the British Ornithologists' Club on "Chilean Bird-Life."

Doctor Chapman has recently returned to the Museum, but Doctor Murphy, who does not expect to return until September, will visit European museums for the purpose of arranging exchanges.

EDUCATION

Closer coöperation between museums and schools was one of the topics occupying a prominent place on the program of the National Educational Association, which held its annual meeting at Philadelphia, June 27 to July 2.

The American Museum of Natural History was represented by Dr. Clyde Fisher, curator of visual instruction and Mrs. Grace Fisher Ramsey, assistant curator of public education. On Monday Doctor Fisher gave an interesting talk on "The Contribution of the Coördinating Council of Nature Activities of the Children's Organizations Outside of the Schools" before the department of science instruction. Mrs. Ramsey served as a member of the program committee for the department of visual instruction.

A new feature of the program which attracted much favorable comment was the demonstration classes using different types of visual aids. Doctor Fisher gave one of these lessons on "Change of Seasons" to a class of totally blind pupils, using the uranosphere which has proved such a wonderful aid in the work carried on by the Museum's department of public education with the blind classes from the public schools of New York City. Later that afternoon he gave a talk on "How the Natural History Museum Can Help the Schools." At the close of the discussion several educational films were shown, among them "The Wonderful Work of Water," prepared from the lecture of Mr. George H. Sherwood, curator-in-chief of the department of public education. At the Tuesday afternoon meeting of the School Garden Association, an allied organization of the National Educational Association, Mrs. Ramsey talked on "The Improvement of Nature Teaching."

FISHES

Mr. J. T. Nichols is now on a reconnaissance trip along the coast of Alaska. His object is to obtain personal field knowledge of certain Arctic forms of birds, fishes, and cetaceans that occur on both the Atlantic and Pacific sides. In a recent letter to Doctor Gregory, Mr. Nichols writes:

"One important and very interesting problem which will be opened by a better field knowledge of the Arctic fauna, has to do with the method and extent to which Pacific temperate forms have invaded the Atlantic, or vice versa, through polar seas. It is conceivable, for instance, that our Atlantic sculpins and flounders were of Pacific origin, became adapted to Arctic conditions, and so crossed to the colder waters of the middle Atlantic. A study of the line where the Arctic fauna meets that of the temperate Pacific, I think along the Aleutians, has a particular bearing on this problem. Here oceanographic conditions pertain which are very different from the better known conditions along the corresponding line in the Atlantic.

"That the fresh-water fishes of North America, particularly the carps and their allies, are of Asiatic origin, I am pretty well convinced. This is evidenced by similarity of fishes in the lower Mississippi Valley to those of Asia, for one thing. An hypothesis as to the time and manner of their crossing, which I have had on my table in the Museum for some months, will be helped by a first-hand knowledge of the present physiography of the Bering Sea region. I shall cover sufficient ground on this trip to see practically all types

of land there bordering on the sea, and should be able to deduce therefrom how different physiography and climate must have been, to have permitted invasion by any particular form."

HISTORY OF THE EARTH

Dr. W. D. Matthew, acting curator of the department of geology and invertebrate palæontology, arrived in Peking in April to spend the summer months in the field with the Museum's Central Asiatic Expedition under the leadership of Dr. Roy Chapman Andrews. Associate Curator Reeds is in charge of the department during his absence. Mr. E. J. Foyles, who has been assistant in the department since 1916, left the Museum on June 30 to accept the position of director of the Geological and Biological Museum in the University of Rochester, Rochester, New York. Mr. D. D. MacLellan, A.M., Columbia, Mr. G. R. Megathlin, A.B., Amherst, and Miss Althea Lepper, A.B., Ohio, are assisting in the department during the summer months. Mrs. Mary V. Forster, A.B., Ohio, is voluntary assistant.

In June, Dr. C. A. Reeds assisted by Messrs. P. B. Hill and F. D. Matlack, resumed field work on the glacial clays of the Hackensack valley, New Jersey. Sampling tools have been devised in the department laboratory for securing continuous specimens of these seasonally stratified clays to depths of thirty-five feet. Through the generosity of Mr. Childs Frick, a one-half-ton Chevrolet truck has been provided for the transportation of the field equipment of this expedition.

INSECTS

The American Museum's Station for the Study of Insects has opened the 1926 season with Dr. Frank E. Lutz in charge and Mr. F. Martin Brown as part-time assistant in the Nature Trail work. The Station has as guests for the summer a number of boys and two research students in entomology, Mr. Wm. S. Creighton, of Princeton University, and Mr. Brandt Steele, of the University of Indiana. As was the case last year, the Nature Trails are open to the public. They are paths in the woods having labels that point out interesting things along the way. The entrance to the Trails is on the Bear Mountain—Greenwood Lake road, near where this road crosses on a bridge the main highway three miles north of Tuxedo, New York.

MAMMALS OF THE WORLD

AKELEY EXPEDITION.—Mr. George Eastman and Mr. Daniel E. Pomeroy have been enjoying some interesting hunting and collecting with Mr. Carl Akeley. Considerable work has been done in the Lukenia Hills in preparation for one of the habitat groups for the African Hall. Early in May the remarkable vegetation of this region was in superb condition for studies to be made. The abundance of flowers in bloom, the rich and varied color of the rocks, and the splendid view of Mt. Kenia to the north and of Mt. Kilimanjaro to the south combine to make this an ideal spot.

Mr. Akeley reports that Messrs. Leigh and Jansson, the artists, are getting excellent results.

THE RUWENZORI-KIVU EXPEDITION.—Late in April Doctor Chapin with his associates, Mr. Sage and Mr. Mathews, made a successful hunting trip into the Tanganyika Territory, with the veteran hunter, Mr. A. J. Klein. They secured three lions, two buffalo, and a variety of antelopes.

During May, they climbed Mt. Kenia in order to select a locality for an East African habitat bird group. On Kenia they collected two genera of birds new to the Museum's collection. In all they have collected nearly four hundred birds. On May 27, the date of the most recent letter from Doctor Chapin, they were just about to go to the Kidong Valley in order to gather materials for a bird group.

The Chapin-Sage party has crossed the trail of the Akeley Expedition, giving opportunity for an exchange of greetings and courtesies.

PERU AND BOLIVIA.—Two expeditions sent out from the department of mammals of the American Museum have recently returned from the field. Mr. G. H. H. Tate, who accompanied Mr. H. S. Ladew to PERU and BOLIVIA, has concluded a successful field season in these countries.

Most of the collecting was done in Bolivia, where material was secured at 24 different collecting stations, ranging from 1800 to 17,200 feet in elevation. The opportunity to acquire museum collections from this district is due to the generosity of Mr. Ladew, who financed the expedition and wished to have a museum representative in his party. Mr. Tate took more than 625 mammals, 200 birds,

and 1500 plants, as well as small collections of reptiles and insects. Since Mr. Ladew's primary purpose was to gain as comprehensive an idea of South America as possible, the party was on the move a large part of the time and covered more territory than is customarily visited in five months. Mr. Ladew left South America by way of Buenos Aires for England, but Mr. Tate remained a few weeks longer in order to round out the collections. Because of a delay in the granting of permits for the shipment, the boxes and trunks of the expedition have not yet arrived at the Museum, hence a more detailed statement as to any rarities secured cannot be given at this time.

VIRGIN ISLANDS AND PORTO RICO.—The object of the second expedition was to collect the mammals of the VIRGIN ISLANDS and small islands adjacent to PORTO RICO. Mr. Gilbert Ottley, volunteer assistant on the trip, returned to New York on June 7, and Mr. G. G. Goodwin, department assistant, concluded the field work and returned on July 5. The party, which left New York in February under the direction of H. E. Anthony, curator of the department of mammals, visited eleven islands during the course of the expedition, Porto Rico, Mona, Caja de Muertos, Vieques, Culebra, St. Thomas, St. Croix, St. John, Tortola, St. Martin, and Anguilla.

Although the mammal life is very restricted throughout the West Indies, great importance may be attached to its distribution and origin, and to the fact that formerly the mammals were more abundant and are found today only as fossils. Valuable collections were secured both of the present-day mammals (the bats) and of the fossil prehistoric forms. Species new to science were taken on St. Martin and, when the collection is properly prepared for inspection, it is not unlikely that additional discoveries will be made. Anguilla and St. Martin, small islands at the northeast corner of the West Indian group, were formerly the home of a very large rodent, a veritable giant compared to the rodents of today. This animal was described under the name of *Amblyrhiza inundata* and must have been as large as a black bear, with a heavy body and robust limbs. The expedition found many teeth and bones of this great rodent, which is very rare in museum collections. Besides a considerable collection of the fossil remains of mammals, birds, and reptiles, 304 recent mammals and small collections of plants and insects were secured. Photographs were taken and data assembled for a detailed report as a part of the natural history survey of Porto Rico and the Virgin Islands, which is being carried on by the New York Academy of Sciences and affiliated institutions.

THE MORDEN-CLARK ASIATIC EXPEDITION.—Recent communications received from the Morden-Clark Asiatic Expedition convey very gratifying reports of splendid success in the quest of *Ovis poli*. The expedition has secured the finest series of this spectacular wild sheep that has ever been brought together for any museum. Although none of the specimens taken is reported to have record horns, excellent group material has been obtained, comprising adult males, females, and young. Interesting side lights on the activities of the expedition are given in letters received by Mrs. Morden and Mrs. Clark. The following is from a letter to Mrs. Clark, dated April 21, from Misgar, India:

"Within the last few days we have passed around the end of four big glaciers and one we had to cross which was a mile and a quarter wide. It was most interesting going up and down, but we could see ice only once in a while, as at best the glaciers are very dirty with the sand and rocks brought down by them. Just above us a hundred yards or so, great pinnacles of ice were standing straight up in the air. This glacier is many miles long, in fact, they don't know just where it starts. One man followed it for 12 days and then didn't find the beginning. Misgar is important as it is the end of the telegraph line on the road to Kashgar. It is only a little flat place in a valley where there is enough water and soil to raise crops. There are two buildings or huts—one the telegraph station and the other a government store house.

"Last night was the end of our comfortable and most convenient rest houses, and tonight we are out in the cold in our little six by seven tents . . . "A" tents. We have no beds and sleep on the ground. . . . . "

"In camp in the Russian Pamirs, 14,000 feet, May 3, 1926. We left on the 30th April, riding yaks, and with ponies carrying our baggage we went over Peyik Pass, 15,450 feet, into Russia. Again we were fortunate in having good weather and we did not have it a bit hard on this trip as we rode the sturdy yaks nearly all the way. The snow on the

Chinese side was not very bad except for the last 500 feet, which were steep, and our ponies floundered pitifully, but finally made it. At the top we all took a rest; it was not cold—about freezing. We had a wonderful panoramic picture from this height and took many photos going over the Pass. As we descended the other side, the snow was much heavier and continued down into the valley for a considerable distance. At times our descent was very steep and we had to zigzag down the slippery slopes. We got to the valley bottom and continued along this for several miles with snow everywhere. . . . "

"Everything is going well. It is a wonderfully interesting trip. We are the first whites to be in here in twelve years, and, we think, the first Americans. We are getting some very interesting pictures too. I am still enjoying good health and find no trouble in breathing although we are higher up. We do not mind the cold. In fact, the cold seems of a mild kind and is not bitter as that we get at home. Of course the outdoor life fortifies one for this and we dress for it too."

From a letter to Mrs. Clark, dated May 9, Russian Pamirs, Aktsoi:

"It is 11 A.M. and we are out on a little knoll watching some sheep and waiting for them to move and get behind something so we can go over some flats after them. Have been here since 6:30.

"I think I told you of meeting the Russians who have been very nice to us. After being with them a day and giving them a chance to size us up we returned to our camp just inside the Russian border. We stayed here because in one section of the mountains near by there were some sheep. They seem to be only in patches and when you know where to look you can see a great many. In other places that look the same you will not see a sheep.

"We have had lots of snow from time to time, which has delayed us some. Have had cold weather too—once zero and always down to 10–15 every night. When the sun is out in the day it gets very warm, like a hot spring day. We have had practically no wind night or day, which saves us from the cold. We are camping in yurts all the time, which are very roomy and comfortable with the little fires. These certainly take the raw edge off of camping, as we go to bed and dress by their warmth.

'We are now up where we have no fuel or water. Everything is frozen and no water runs. Our fuel has to be brought to us from the flats below,—many miles, and we melt snow for water. At our last camp No. 29 we saw many sheep and got two fine big ones out of a herd of 20 rams. Bill shot one and I got a good one at the same time. That was the morning of zero weather and it was bitterly cold riding along. We travel on yaks when hunting, as they alone can get through the deep snow and climb the hills over rocks or snow at this high altitude. They are strong and powerful and very good to ride, and carry all you want to tie on them.

"I went out alone one afternoon and saw 33 sheep, rams, and females, but when they are in such numbers they are very hard to hunt, as they scatter out. There are always some that see you and the minute they do off they go over the mountain peaks and you have to hunt them the next day in another valley, hoping always to see them first so you can stalk. This is difficult as the country is all big, sweeping valleys and the sheep nearly always see you before you see them. We chased them so much and there were so many storms that we decided to move to this place that we heard of. We made the 30 miles in two marches, passing Kizil Rabat again and seeing the soldiers, and stopping at the hot springs for another nice hot bath. . . ."

"The skins of the *Poli* are extremely hard to take care of. . . you usually get them a long way from camp, but most of all, the hair is extremely brittle and sensitive to blood stains that won't come out. Then the weather is almost always at freezing and the sheep are hard to wash and skin. You will remember the trouble I had with the caribou—well, these are very much worse. They are still in the fine winter coats of a sort of brown back with cream white legs and underparts. We have seen several foxes but could not shoot them while hunting the sheep. Their fur is not of good color, being sort of a dirty white. Saw one wolf and some rabbits. The marmots are just beginning to come out in the middle of warm days. They are big fellows and the color of a dark red fox. I want to get some if I have a chance. We have to be very careful about shooting in the sheep country, as it scares them too much. . . ."

"Have been through some glorious mountain country and have hunted up to 15,500 and 16,000 feet. We are in camp 34 now, so you we see are moving fast. Have altogether 5 specimens of *Ovis poli*—all 5 are

big males—horns measuring from 50 to 52 inches. Have a complete skeleton and 4 skins. The weather is cold at night, going down to about 15 more or less every night. The days when the sun is out are like balmy spring days and at times hot. When clouds come up it is quite cool, but not cold. The Russians are still very kind to us and are doing everything possible to help in every way. As yet we have heard nothing further from Roy and don't know whether we will go out with him or not. We expected something definite before this, but he promised to let us know at Kashgar June first."

Later on other specimens of *Ovis poli*, in addition to the five mentioned above, were secured.

Because of the disturbed political conditions in China, which have upset the plans of the Third Asiatic Expedition, the Morden-Clark Asiatic Expedition will not be able to meet Doctor Andrews as originally planned.

SCIENCE OF MAN

Professor A. Radcliffe Brown recently visited the department of anthropology, en route to Sydney, Australia, where he has been appointed to the new chair of anthropology in the University of Sydney. Professor Brown has long been distinguished for his anthropological work, both in the field and as a teacher. As a preliminary to his work in Australia he has made a tour of American institutions interested in anthropology to investigate their methods and examine museum collections.

Earl H. Morris, who up to the present year, was in full charge of the Museum's intensive exploration of the Aztec Ruin, now the Aztec National Monument, New Mexico, recently spent a few days at the Museum. Mr. Morris has been appointed by the Carnegie Institution of Washington to take charge of the excavation of the famous Maya ruin at Chichen Itza, Yucatan.

The Fifth Bernheimer Expedition.—A report was received during the month from the Fifth Bernheimer Expedition announcing some interesting finds. This expedition spent twenty-three days in the general region of Navaho Mountain in New Mexico to secure anthropological, geographical, and geological data.

A new natural bridge was located, the hemispherical arch of which was 170 feet high. Its spread from base to base was about the same, and its thickness at the top was in the neighborhood of 25 feet. Mr. Bernheimer reported that a remarkable feature about this bridge was its removal about thirty feet from its matrix, which, immediately back of it and almost concentric with the fully developed natural bridge, was in process of forming another natural bridge, while within the center of the latter there was still another round cavity developing. This suggested the eye of a hawk, hence the name, Hawkseye Bridge, was given to the formation.

Shortly afterward the party located a ridge of slick rock about a mile square. This ridge was literally covered with pot holes of all sizes, several of them very deep. Some contained water, and others sand. Vegetation grew luxuriantly in the sand, while some of the sand-filled holes were deep enough to house cedars from two to four hundred years old. A number of holes were from thirty to forty feet deep, and varied in diameter, from ten feet at the base to twenty to forty feet at the mouth. Inasmuch as the watershed was insignificant, it was decided that the action of the wind was mainly responsible for them, perhaps assisted by the rotting of the stone under the influence of water.

PUTNAM ARCTIC EXPEDITION

Friends of the Expedition, which has Mr. Putnam, Mr. H. C. Raven, and Mr. Van Campen Heilner aboard, had an anxious time when they learned that the Schooner Morrissey had run on the rocks, and they were correspondingly relieved at the message that the schooner had been safely floated and was proceeding on its way undamaged. Among the trophies of the expedition are five Greenland sleeper sharks, one of which is ten feet long, as announced by wireless to the New York *Times* July 21.

J. L. WORTMAN

A brief letter from Mrs. Eugenie Wortman of Brownsville, Texas, announces the death of Dr. J. L. Wortman, June 26. Doctor Wortman was one of the prominent palæontologists in America for several years. He collected fossils for the American Museum in 1890, and in 1891, when the department of vertebrate palæontology was organized, he was appointed assistant curator, an office which he filled until he resigned from the Museum staff in 1898. A fitting tribute to this noted scholar, with a record of his achievements, will be printed in the next issue of Natural History.—B. B.

NEW MEMBERS

SINCE the last issue of NATURAL HISTORY, the following persons have been elected members of the American Museum, making the total membership 9025.

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THE ROMANCE OF FOSSIL HUNTING

SEPTEMBER-OCTOBER

The September-October issue of **Natural History** will deal with the fascinating experiences of collectors in searching the rocks of different ages for specimens of former life.

Geologic time is very long—perhaps one and a half to two billion years—no one knows the exact length. The fossil record of plants and animals, that once lived in the sea and upon the land, is far from complete and probably never will be fully known, for of the thousands of individuals that lived only the hard parts of a few are preserved in the sedimentary rocks. Oftentimes only a bone, a scale, or a bit of broken shell is the collector's reward for the day's search. Again, he may be overwhelmed with the great abundance of material. Complete specimens are rarely found. It is the duty of a fossil collector to know his science so well that if only a part of a specimen is unearthed he can immediately interpret its relation to the former individual and its significance in geologic time.

The surface of the land and the depths of the sea have not always been the same as they are at present. The plains, hills, mountains, streams, and valleys have had many different settings. The sea during various stages has pushed its strand line inland over the lowlands to a far greater extent than now. As the student of earth history becomes familiar with these varied scenes, he notes that the plant and animal life, on both land and sea, has been ever changing; that the forms are related; that there has been both progressive and regressive evolution, and that living things are what they are because of their connections with the past.

Mr. Childs Frick, trustee and research associate of the American Museum of Natural History, in an entertaining article on "Prehistoric Evidences" contrasts the former life of Val d'Arno and Monte Bamboli, Italy, with the Rancho-la-Brea tar pool of California and the extinct Pleistocene and Miocene faunas found near Santa Fé, New Mexico.

Dr. W. D. Matthew, well-known palæontologist of the Museum, in "Fossil Hunting on the High Plains" tells of some of the methods used in collecting fossils twenty years ago as compared with those of today.

Associate Curator Barnum Brown of the Museum staff and veteran collector in many lands has chosen "The Samos Island Fossil Fields" for relating his fossil-hunting experiences in the Grecian archipelago.

Professor R. S. Lull, director of the Yale University Museum, in "Early Fossil Hunting in the Rocky Mountains" dwells upon the trials and fortitude of the pioneer palæontologists—Marsh, Cope, Hatcher, Wortman, and others.

Dr. Stuart Weller, professor of palæontologic geology in the University of Chicago, reveals his intimate knowledge of the Mississippi Valley rocks and of the fossils found therein.

Professor J. E. Hyde, of Western Reserve University and of the Cleveland Museum of Natural History, contributes an article on the "Fossil Fishes of the Cleveland Shale" and adds a personal touch concerning the collectors who have unearthed these unusual forms.

Dr. Rudolf Ruedemann, Palæontologist of the State of New York, recounts his interesting experiences as a fossil collector. New York State is rich in fossils of the Palæozoic age, and has produced many notable collectors.

Professor W. H. Twenhofel, of the University of Wisconsin, tells of his varied experiences as a fossil collector on the wild and storm-ridden island of Anticosti.

Professor Edward W. Berry, of Johns Hopkins University, one of the few palæobotanists in the United States, relates some of his interesting experiences as a collector of fossil plants.

Dr. Robert Broom, physician and veteran collector of Permian reptiles, tells of "Fossil Hunting in South Africa."

Several members of the staff of the Museum's Central Asiatic Expedition have contributed to "The Romance of Fossil Hunting in Mongolia," which summarizes briefly the essential features of the Expedition's work in the Gobi Desert.

"The Arbuckle Mountains, Oklahoma—The Fossil Collector's Happy Hunting Ground" will be described by Dr. Chester A. Reeds, associate curator of invertebrate palæontology.

Dr. A. Wetmore of the United States Natural Museum and Curator E. S. Riggs of the Field Museum of Natural History will also contribute.